REVIEW ARTICLE

Priorities in Perioperative Geriatrics

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The aging of the baby-boom population and the decreases in adult mortality seen in the last few decades will dramatically increase the age of Americans between 2010 and 2030. During that time, the population older than age 65 yr is expected to grow by 75%, whereas between 1995 and 2050, the cumulative growth of the population older than 85 yr is expected to exceed 400% (1). Furthermore, it has been reported that the increased demand for surgery in this population may exceed the rate of population growth (2).

The implications of an aging population for the practice of anesthesiology are profound. Age-related changes in physiology and pharmacology can affect every aspect of perioperative care. The changes in surgical demographics will compel the anesthesiologist to become familiar with the physiology and clinical care of the aged. This review will serve as an introduction. First, some of the physiologic changes that occur with aging will be presented. Second, the preoperative assessment of the older surgical patient will be discussed. Third, some of the research related to intraoperative management of the geriatric surgical patient will be described. In the fourth section, we will discuss some geriatric-specific issues related to postoperative management.

Physiologic Changes Relevant to Perioperative Care

The most important generalization from physiologic studies of aging is that the basal function of the various organ systems is relatively uncompromised by the aging process *per se*. However, functional reserve and the ability to compensate for physiologic stress are reduced (Fig. 1).

Cardiovascular Changes

Cardiovascular changes with aging have implications for anesthetic care. Changes in the vascular system and hemodynamics can affect every organ bed. The Framingham Heart Study documented a nearly linear increase in systolic blood pressure from age 30 to 84 yr (3). Age-related hypertension is attributable to a 50%–75% increase in arterial stiffness and a 25% increase in systemic vascular resistance (3,4). Increased sympathetic nervous system activity and decreased peripheral β-adrenergic responsiveness further contribute to the hypertension of aging (5).

Ventricular hypertrophy develops in response to increased afterload, increasing wall stress, myocardial oxygen demand, and increasing susceptibility to ischemia. Although intrinsic contractility and resting cardiac output are unaltered with aging, ventricular hypertrophy and stiffening limit the ability of the heart to adjust stroke volume (6) and impair passive ventricular filling. In the elderly, changes in ventricular end-diastolic volume in response to either positive or negative changes in central venous pressure are typically half those seen in young or middle-aged subjects (7). At the same time, fatty infiltration and fibrosis of the heart increases the incidence of sinus, atrioventricular, and ventricular conduction defects (8). With aging there is also decreased myocardial responsiveness to catecholamines and a diminished heart rate response (6). These processes compromise the heart's ability to buffer changes in circulatory volume, resulting in a disposition to either congestive heart failure or hypotension.

From the standpoint of perioperative hemodynamic stability, age-related changes in the autonomic control of heart rate, cardiac output, peripheral vascular resistance, and the baroreceptor response (7,9,10) are as important as the changes in the myocardium and vasculature. Age-related changes in the cardiovascular system involve alterations in both mechanics and control mechanisms; the same can be said of the pulmonary system.

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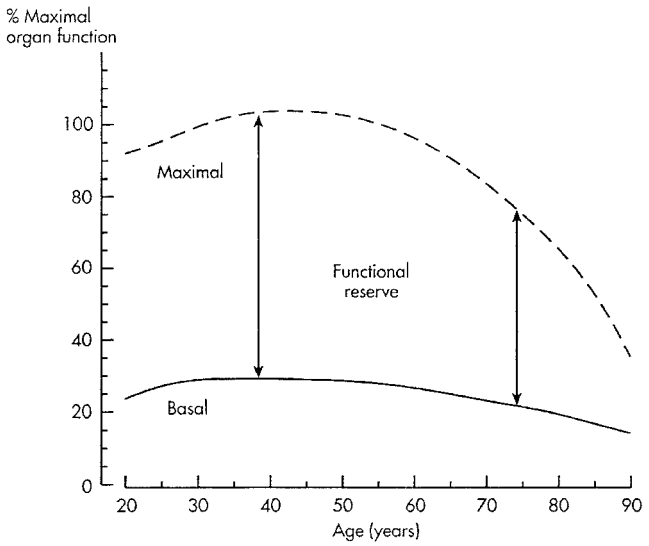

Figure 1. Schematic representation of the relationship between maximal (broken line) and basal (solid line) physiologic function. Functional reserve is the difference between maximal and basal function. Aging inevitably reduces functional reserve even in individuals who are physiologically "young." The configuration of the curve for basal function is adapted from longitudinal measurements of total (not weight-specific) basal metabolic rate. Reprinted with permission: Muravchick S. Geroanesthesia: principles for management of the elderly patient. St. Louis: Mosby, 1996 (Figures 1–3).

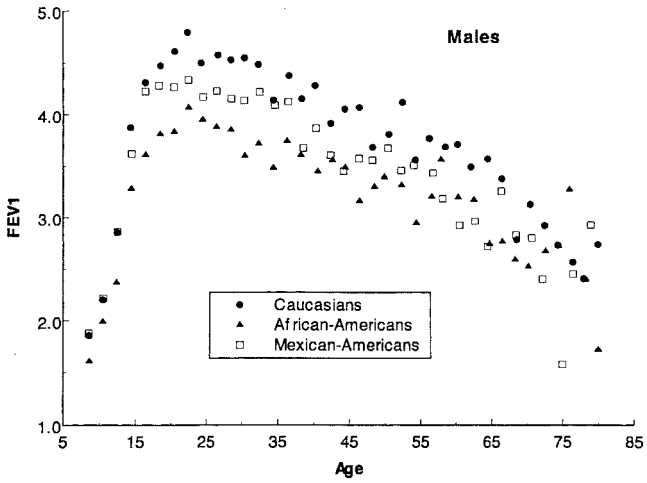

Figure 2. Mean forced expiratory volume in 1 s (FEV_1) versus age for men of differing ethnic groups. Reprinted with permission: Am J Respir Crit Care Med 1999;159:179–87 (Figure 1).

Pulmonary System

Age-related changes in the pulmonary system parallel changes in the heart. With time, the thorax becomes stiffer, increasing the work of breathing and reducing maximal minute ventilation (11,12). Loss of thoracic skeletal muscle mass aggravates this process. Residual volume and functional residual capacity (FRC) both increase with age—5%–10% and 1%–3% per decade, respectively—whereas the forced expiratory volume in 1 s is reduced approximately 6% to 8% per decade (Fig. 2) (11,13). Because of reduced elastic recoil, the closing volume increases such that it exceeds FRC by age 65 (14). In the supine position, closing capacity may reach FRC by 44 yr of age (11). Inspiratory and expiratory functional reserve decrease with aging, and the normal matching of ventilation and perfusion decreases (15). The respiratory response to hypoxia also diminishes with aging (16); there is a decrease in ciliary function, and cough is reduced (11). Finally, pharyngeal sensation and the motor function required for swallowing are diminished in the elderly (17,18).

Neurologic Changes with Aging

Cardiopulmonary complications account for most morbidity and mortality in older surgical patients; however, neurologic morbidity affects a large number of patients, and age-related degenerative changes in the central and peripheral nervous systems contribute to a variety of other morbidities.

Both the central and peripheral nervous systems are affected by aging (19). There is a decrease in cortical gray matter through middle age, resulting in cerebral atrophy (20). The ratio of gray to white matter decreases from 1.28 at 20 yr to a low of 1.13 at 50 yr, followed by an increase of this ratio to 1.55 at 100 yr of age. The latter increase appears to reflect a disproportionate loss of white matter in the latest decades (20). For the cortical gray matter, a decrease in neuronal volume appears more important than neuronal loss (21,22). There is also a reduction in the complexity of neuronal connections, a decrease in the synthesis of neurotransmitters, and an increase in the enzymes responsible for their postsynaptic degradation (20). Although cerebral metabolism, blood flow, and autoregulation generally remain intact (20), dendritic regression and the deficiency of neurotransmitters limit the ability of the older brain to integrate multiple neural inputs. Neuronal loss and demyelinization also occur in the spinal cord (23). Functionally, there are changes in spinal cord reflexes and reductions in proprioception. There are also important decreases in hypoxic and hypercarbic drive (11,24). Declines in visual and auditory function further complicate the ability of the nervous system to acquire and process information. This combination of changes can limit the ability of the older patient to understand and process information in the perioperative period. These changes are probably important contributors to postoperative delirium, drug toxicity, and falls.

Aging is also associated with neuronal loss in the autonomic nervous system. Sympathetic and parasympathetic ganglia lose neurons, and there is fibrosis of peripheral sympathetic neurons. This peripheral neuronal adrenergic loss is associated with impairment of cardiovascular reflexes. At the same time,

decreases in adrenoceptor responsiveness result in increased adrenomedullary output and plasma catecholamine concentrations (9,10,23). Circulating norepinephrine levels have been reported to increase approximately 60% (230 to 380 pg/mL) between age 20 and age 70 (10).

Skeletal muscle innervation decreases, translating into a loss of motor units and a decrease in strength, coordination, and fine motor control (25). Joint position and vibration sense may be compromised, and the literature suggests some diminution in the processing of painful stimuli (26,27). However, this effect, if it exists, appears to be modest at best and does not affect all nerve types equally (27–29). Furthermore, given huge interpatient variability in nervous system function and in the experience of pain, alterations in subtypes of pain perception do not translate into a decreased need for analgesia in the elderly (29–32).

Renal

Aging is accompanied by a progressive decrease in renal blood flow (approximately 10% per decade after age 50) and loss of renal parenchyma (33). Furthermore, by the eighth decade, 10%–30% of remaining nephrons are sclerotic, reducing the functional capacity of the reduced nephronal number (34). Together these processes result in a progressive decrease in glomerular capillary surface area and glomerular filtration rate. However, because of loss of muscle mass, aging is not associated with an increase in serum creatinine. This physiologic, and often occult, aspect of senescence has practical implications in the perioperative period.

The old kidney has difficulty in maintaining circulating blood volume and sodium homeostasis perioperatively (9,35). Fluid homeostasis is further complicated by alterations in thirst mechanisms and antidiuretic hormone release that frequently result in dehydration (35). Perioperatively, metabolic acidosis is also relatively common in elderly patients who are less efficient in the renal excretion of acid.

Reductions in basal renal blood flow and a diminished response to vasodilatory stimuli (33,36) render the elderly kidney particularly susceptible to the deleterious effects of low cardiac output, hypotension, hypovolemia, and hemorrhage. Anesthetics, surgical stress, pain, sympathetic stimulation, and renal vasoconstrictive drugs may all compound subclinical renal insufficiency.

Aging: Pharmacokinetics and Pharmacodynamics

Our knowledge of the pharmacology of aging is limited by the fact that elderly patients are often systematically excluded from drug trials (37). This is a travesty because elderly patients are the largest users of prescription drugs. That said, certain predictions can be made about pharmacology in the elderly. With aging there is decreased lean body mass and total body water and an increased proportion of body fat; these alter the volume of distribution and redistribution of drugs and alter their rates of clearance and elimination. In a study of population pharmacokinetics for propofol, elimination clearance of the anesthetic was found to decrease linearly with age >60 yr, even correcting for changes in body weight (38). Furthermore, even though age-related changes in plasma proteins make generalizations about the pharmacokinetics complex, decreased protein binding and increased free fraction have the potential to increase the pharmacologic effect of drugs used perioperatively (39). Furthermore, alterations in cardiac output and renal or hepatic clearance may change drug plasma concentrations and their duration of action (40). Neuronal loss and decreased levels of neurotransmitters may increase sensitivity to anesthetics. The changes in pharmacokinetics that occur with aging make it difficult to identify an independent effect of aging on pharmacodynamics (41). However, age-related changes in the central nervous system appear to increase the sensitivity to a variety of anesthetics (42,43). This is probably best described for propofol, where elderly patients are approximately 30%–50% more sensitive than younger patients (44); this sensitivity is independent of the decreased clearance of the drug.

Pharmacokinetic and pharmacodynamic changes, together with drug interactions and polypharmacy, conspire to make the elderly prone to adverse drug effects. There is an almost linear increase in adverse drug reactions with age (45,46), and the likelihood of adverse drug reactions increases with the number of drugs administered. The addition of several drugs, even short-acting ones, in the perioperative period makes adverse reactions likely.

Implications

What is clear from a review of the physiologic changes with aging is that even the fit elderly patient's ability to compensate for perioperative stress is compromised. The cardiac, pulmonary, neurologic, and neuroendocrine changes that occur with aging make hypotension, low cardiac output, hypoxia, hypercarbia, and disordered fluid regulation more commonplace in the perioperative period. Furthermore, because baseline cardiac, pulmonary, renal, and neurologic function is typically adequate in the absence of acute challenges, it can be very difficult to predict the effect of perioperative stress on the older patient.

Preoperative Assessment of the Elderly

Historically, preoperative assessment has served to alert the surgical care providers to physiologic conditions that may alter perioperative management and to

determine whether medical intervention is indicated before proceeding. Two more contemporary uses of the preoperative assessment are to provide an index of risk and therefore contribute to decisions about the most appropriate intervention and to provide baseline data on which the success of a surgical intervention might be judged.

Despite physiologic changes with aging and multiple comorbidities, even extreme age is not a contraindication to surgery (47–49). What is less clear is how to identify which patients will do well and which will do poorly. No area of perioperative anesthetic care and management requires more investigation. The preoperative assessment of the patient is composed of four interrelated functions: risk stratification, as defined by population-based studies; history and physical examination, including functional assessment of the individual patient; preoperative testing; and, in some cases, preoperative optimization.

Population Studies. Because age itself adds little additional risk in the absence of comorbid disease (50), most risk factor identification and risk predictive indices have been disease oriented (51–55). These investigations have typically studied a broad age range of patients and in multivariate analyses identified the relative contribution of age, ASA status, specific surgical factors, intraoperative management, and comorbid conditions to surgical morbidity and mortality (52,53,56–60).

The applicability of many existing risk indices to the geriatric population is unclear. Because of the prevalence of comorbid conditions, it is difficult to stratify the older patient population into smaller subsets with better-defined risk. The scarcity of population studies of perioperative risk and outcomes specifically in geriatric populations can make it difficult to provide good information or to choose the most suitable course of care. Furthermore, elderly patients have relatively unique risks. In addition to death, myocardial infarction, or congestive heart failure, older patients are unusually prone to postoperative delirium, aspiration, urosepsis, adverse drug reactions, malnutrition, falls, and failure to return to ambulation or to home. Therefore, preoperative assessment tools and the variables evaluated in outcomes trials require expansion for application to the geriatric surgical population. Once completed, epidemiologic studies that better stratify older patients would help to define the appropriate preoperative assessment.

Functional Assessments. Functional evaluation of elderly surgical patients requires greater attention. This is important for several reasons. First, the evaluation of the "resting" patient does not indicate how the patient will respond to perioperative physiologic demands. Second, because of patient heterogeneity, functional assessments may be indicated to better characterize patient differences, whether it is for activities of daily living, cognitive and emotional status, or urologic function. Although these metrics have been applied successfully in orthopedic and thoracic surgery (61–63) and can have predictive value for longer-term outcomes (64–68), multidimensional assessment and perioperative functional assessment are largely lacking in the surgical literature. Preoperative functional assessment is important because the surgical goal should be to return the patient to at least the preoperative activity level. Tools such as the Short-Form Health Survey 36, with subscales for variables such as physical and emotional health, pain and health perception, and social functioning, can be used to measure health-related quality of life before and after surgery (Fig. 3). These types of multidimensional assessments have the potential to help redefine standards for the success of surgery and reset therapeutic priorities (61,62,69–71).

Preoperative cognitive and psychological evaluation of the elderly surgical patient deserves special comment. Although frank delirium or dementia at admission is very evident and is known to predict poorer acute and long-term outcome (72,73), subtle forms of cognitive impairment are much more common. Subtle forms of cognitive impairment can predict subsequent delirium (74) and worsened cognitive outcome in cardiac, orthopedic, and abdominal surgery patients (75–78). As such, a preoperative mental status examination (79) should be considered in all geriatric surgical patients. Preoperative depression and alcohol abuse are also relatively frequent and can affect outcomes (72,80,81); as with mental status batteries, a variety of assessment tools for depression are available. The effect of screening for mental status, depression, and alcohol abuse on perioperative management of elderly patients is a huge potential area of investigation.

Preoperative Testing. The third area contributing to the preoperative preparation of the elderly surgical patient is preoperative testing. Although work in this area has been performed for large populations of mixed age groups, it is not clear whether preoperative screening tests have a different yield in the elderly or whether specific testing is indicated for elderly patient populations undergoing certain types of surgical procedures.

In the general population, the bulk of routine tests are not indicated. Unfortunately, age-specific data are uncommon, and some small studies in elderly populations suggest a larger yield for specific tests. For the elderly surgical population, chest radiograph, electrocardiogram, and urinalysis may have a larger yield in patients undergoing certain types of procedures, even if these tests are not directly predictive of postoperative complications (82,83).

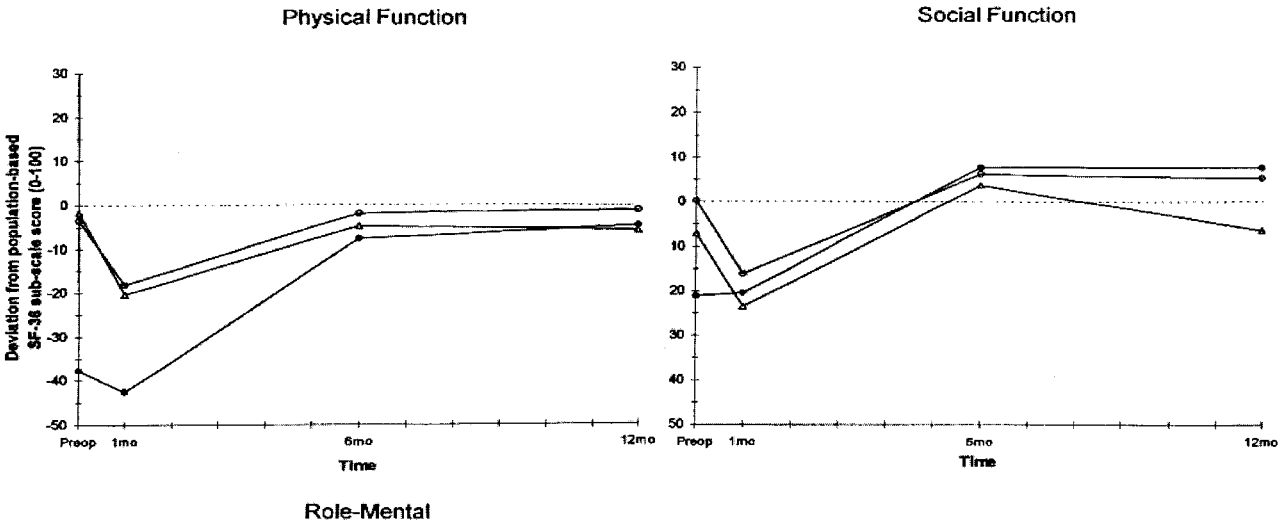

Figure 3. Deviation from age- and gender-adjusted population-based Short-Form Health Survey 36 scores (subgroup scores by surgical procedure). △ = thoracic surgery for lung cancer; ● = total hip arthroplasty; ○ = abdominal aortic aneurysm; dotted line = age- and sex-adjusted population-based value. Modified with permission from Blackwell Publishing: J Gen Intern Med 1997;12:686–97 (Figure 2).

In a small study of acutely ill elderly medical patients, the value of screening tests was evaluated (84). The most important finding in the screening battery was unknown urinary tract infections (16 of 50 patients; 32%). A different retrospective analysis (85) of 86 hip arthroplasty patients also determined that routine urine analysis was cost-effective in reducing hip infections in the elderly.

Nutritional assessment can also be useful in subpopulations. The 44-center Veteran's Administration (VA) study found that albumin concentration was a predictor of surgical outcomes (86). However, because of wide confidence limits, laboratory assessments of nutritional status may make their application to individual patients less useful than to populations (87). As such, it may prove useful to combine laboratory tests with anthropomorphic measurements, such as body mass index, limb circumference, and weight loss (88–90). These instruments are simple and inexpensive, but their clinical yield has not been determined.

From these investigations and from work in younger subjects, three themes become evident. First, routine, undirected screening in a general population of elderly patients does not add significantly to information obtained in the clinical history. Second, in a general population, the positive predictive value of abnormal findings on routine screening is limited. Third, with only a few exceptions, screening tests have relatively little effect on the course of patient care. Despite those observations, further research is required to better define the circumstances under which certain tests should be ordered.

Although the yield for routine screening is very small, it may be clinically valuable and cost-effective to develop guidelines for preoperative testing that are based on the type of surgery. Differing types of surgery impose different types and degrees of physiologic stress. As such, the results of a cataract trial (91) are inapplicable to patients undergoing vascular surgery. Preoperative tests such as echocardiography and thallium scanning can have predictive value and alter the course of care if applied to specific populations at increased risk (51,92,93). Similarly, nutritional assessment might be very useful before abdominal or major orthopedic surgery, but it would have a much smaller effect for carotid endarterectomy. Screening for urinary tract infection before orthopedic surgery or pulmonary function testing before thoracic surgery might be representative of surgery-specific laboratory testing. Because it is the interaction of the patient and the surgical stress that determines outcome, specific testing might be equally indicated in a very physiologically debilitated older patient undergoing minimally stressful surgery and in the mildly compromised older patient undergoing surgery that imposes severe physiologic stress. Future studies in older patients will need to stratify patients as to severity of their preexisting risk factors (low, intermediate, or high) and specifically examine their interaction with the specific surgical challenges most common in the elderly.

Preoperative Optimization. In addition to providing 1) an assessment of risk based on population studies, 2) functional data to help define surgical success, and 3) specific information to guide perioperative management, the fourth purpose of preoperative evaluation is to determine whether medical intervention is indicated before proceeding. Preoperative optimization is an area in which relatively little geriatric research has been performed. In specific populations undergoing

high-risk surgery, the value of preoperative optimization of cardiac and pulmonary status can be demonstrated (92–98). Improvement in nutritional status, preoperative hydration, or renal function has the potential to alter outcomes but has not been investigated. Preoperative management of antibiotic therapy, anticoagulation, antiplatelet therapy, and anemia are other obvious areas to examine. There are also suggestions that preoperative interventions might facilitate pain management and rehabilitation (99,100) and reduce delirium (101) after some types of surgery. Typically, where success has been shown in these areas, a multidisciplinary approach (92,98–100), sometimes with a specific geriatric care team (101), was used.

Intraoperative Management

Because anesthetic care is episodic, the criteria for success are typically short-term and are not related to mortality and major morbidity. Investigation of drugs and techniques often address variables such as extubation and recovery room time. Much of the recent work specific to the elderly has been devoted to evaluation of ultra-short-acting anesthetics.

Although some of these studies have identified age-related alterations in the pharmacokinetics, induction, awakening, or recovery room stay, perspective is needed. Whereas a drug may shorten recovery room time by 30 min, the clinical effect of these changes on patient outcomes is probably minimal. There is a role for this type of research in geriatrics, but primary research efforts should probably be directed elsewhere. In addition to the numerous studies on the pharmacology and short-term recovery in aged, surgical patients, a second major area of research effort has been to compare regional and general anesthesia.

Regional Versus General Anesthesia. Anesthesiologists caring for elderly orthopedic patients have been the *de facto* leaders in research in geriatric anesthesia. Research comparing regional and general anesthesia in elderly orthopedic patients has broad implications for determining research directions. These studies have examined intraoperative cardiovascular stability in the elderly, cardiopulmonary and thrombotic complications, pain control, and cognitive outcomes. Much of this literature was reviewed by Roy (102).

Although a few early studies reported that regional anesthesia for orthopedic surgery was associated with better outcomes (103,104), subsequent investigations have not confirmed this across broad populations of patients (105–108). Because most investigations have been underpowered for rare events, metaanalysis has been useful.

Sorenson and Pace (105) examined 13 randomized controlled trials that reported follow-up to at least 1 mo. The authors were unable to identify any difference in mortality or blood loss by regional or general anesthetic technique, although there was a clearly reduced incidence of deep vein thrombosis (DVT) in regional anesthesia groups. Much of the data in Sorenson and Pace's study were more recently reanalyzed with the addition of additional trials (106). Like Sorenson and Pace, Urwin et al. (106) described reduced DVT and 1-mo mortality in 2162 hip fracture patients receiving regional anesthesia, although no other outcome measure reached statistical significance. The reduction in mortality was no longer evident at 3, 6, or 12 mo. Subsequent large single-center observational studies (109–111) have also not identified meaningful differences in cardiopulmonary morbidity or mortality by anesthetic choice in hip surgery patients. A similar conclusion was reached in the 2002 Cochrane Library review (112).

The review by Rodgers et al. (113) examined the effects of regional anesthesia in 141 randomized trials that included 9559 patients. A reduction in 30-day mortality and DVT was observed in the regional group, with no effect on mortality beyond 1 mo. Reductions in pulmonary embolism, transfusion, respiratory depression, myocardial infarction, and renal failure were also described with regional anesthesia. However, the reporting of many of these outcomes was incomplete, so the analysis was based on small subsets of patients. Additionally, studies were not rated for quality, and data were used that were not reported in the published trial. Furthermore, studies for general, obstetrical and gynecologic, urologic, orthopedic, and "other" surgeries were combined, and no information about age was provided. Finally, it is impossible to base a practice on the results of the review of Rodgers et al. because the following groups of patients were combined into the regional anesthesia group: those receiving 1) spinal anesthesia alone, 2) epidural anesthesia alone, 3) general anesthesia followed by postoperative regional anesthesia, 4) general anesthesia combined with intraoperative spinal anesthesia, and 5) general anesthesia combined with intraoperative epidural anesthesia. From this it is difficult to determine whether the effects described in the review are real and, if so, what their origin is or to what patients they would apply.

In addition to the more typical outcomes measures, several studies in orthopedic patients have examined the effect of anesthetic technique on cognitive or functional outcome, often following patients for $\geq$3 mo. Although each of the prospective studies is small, only one study (104) identified any difference in cognitive outcome in elderly patients undergoing regional versus general anesthesia for orthopedic surgery. The bulk of investigations could identify no difference (80,114–117).

Although not all studies are in agreement (118,119), similar conclusions must be drawn for transurethral prostatectomy and peripheral vascular surgery

(117,120–122). In carotid surgery, there is a suggestion of a better outcome with a regional technique; however, most investigations are retrospective or nonrandomized, so the effect of patient selection cannot be eliminated. Additionally, the multicenter North American Symptomatic Carotid Endarterectomy Trial (123) could not identify an independent effect of anesthetic technique on outcome.

The difficulty in identifying a meaningful difference between regional and general anesthesia has tremendous implications for the conduct of research in geriatric anesthesia. First, because the most substantive difference in the choice of anesthetic is whether the patient undergoes a regional or a general anesthetic, if little or no difference in outcome can be identified, then the yield for similar outcome studies on differing anesthetics is likely to be small. Second, it follows that studies on anesthetic management and outcome will need to be directed to specific complications in higher-risk patients to provide clinical yield.

Physiologic Management. Although numerous studies have examined the relationship between intraoperative physiologic management and outcome, outside of catastrophic events, it appears that physiologic management plays a modulatory rather than a primary role in outcome. The best example is in cardiac surgery, in which the acute physiologic changes exceed those seen with any other type of surgery. Despite that, it has been difficult to demonstrate a direct relationship between physiologic management and outcome. Rather, it appears that technical issues during surgery and the risk factors that the patient brings to the operating room primarily determine how well the patient does.

These conclusions are not an indictment on anesthetic practice or the role of the anesthesiologist in the operating room. The opposite is true. Over the last three decades, anesthesiology has made tremendous strides that have made the intraoperative period extremely safe. Those advances will continue to expand what is possible surgically. At the same time, it is because the advances in intraoperative care have been so great that the greatest needs for research in geriatrics probably lie in the preoperative assessment and the postoperative management of patients.

In perspective, the lack of an independent effect of anesthetic choice or physiologic management on major outcomes is not surprising. In very large studies of perioperative morbidity and mortality, the anesthetic episode *per se* appears to have little or no effect on 30-day outcomes (60,124). Whereas certain pathophysiologic processes may be initiated during the intraoperative period, with few exceptions, major morbidity and mortality in the operating room are rare.

Although choice of anesthetic should not be our research priority in perioperative geriatrics, when these studies are conducted, they must focus on the elderly population, who will continue to constitute a growing segment of the surgical population. Outside of anesthetic choice or physiologic management, there are other broad areas related to intraoperative care in which research in the elderly might be productive. Anesthetics and alterations in autonomic function make it more difficult for older patients to maintain their body temperature, and because postoperative hypothermia increases the risk of adverse outcomes (125,126), temperature control in elderly surgical patients will continue to require attention. Other areas of intraoperative care outside of anesthetic choice are the appropriate role for prophylactic antiplatelet drugs and histamine-2 blockers in elderly surgical patients. Other potentially fruitful areas might be the immunosuppressive effects of blood transfusion, musculoskeletal and nerve injury, and perioperative thrombotic complications. Similarly, fluid intake and hydration status and their relationship to renal insufficiency, hypovolemia, and aspiration risk in the elderly would be an area of research with a large potential effect on practice.

Postoperative Management

Most surgical morbidity and mortality occurs after surgery. In 7306 adult patients undergoing noncardiac and nonthoracic surgery, Pedersen et al. (57) found that mortality in the first 24 postoperative hours was twice as frequent as that seen under anesthesia and that the mortality over the next six postoperative days was 10-fold more than seen during surgery. The same was true of morbidity.

Postoperative Respiratory Complications. Respiratory complications are the most common morbidity after noncardiac surgery. Although smokers are probably overrepresented in Veteran's Administration (VA) studies, 17% of the 84,000 patients in the 1995 VA study of noncardiac surgical patients had complications. Of those who had complications, pneumonia occurred in 3.6%, ventilatory failure in 3.2%, and unplanned intubation in 2.4% (59). In a study of 288 older general surgical patients, Seymour and Vaz (127) reported that 17% of patients developed atelectasis, 12% acute bronchitis, and 10% pneumonia.

Because the age-related changes in respiratory mechanics and control are accentuated by pain, anesthetics, neuromuscular blockers, atelectasis, fluid shifts, and other postoperative physiologic changes, the elderly have a disproportionate number of respiratory complications. Despite this, clear guidelines for respiratory monitoring in the elderly have not been developed. This issue is of pressing importance as continued efforts are made to abbreviate the time to discharge and as more patients, most of them elderly, undergo conscious sedation outside the operating

room, where the risk of death related to sedation is increased (128).

Age-related alterations in pharyngeal function and diminished cough are aggravated by anesthetics, muscle relaxants, pharyngeal instrumentation, and upper abdominal or neck surgery (18,129–133). As such, efforts to reduce postoperative aspiration in the elderly are also indicated. Although the incidence of intraoperative aspiration is small and is uncommonly associated with clinically important pneumonitis (134), the greater risk for aspiration extends after surgery. Research focusing on appropriate reversal of neuromuscular blocking drugs, use of nasogastric tubes, restoration of pharyngeal and tracheal reflexes and gastrointestinal motility, and advancement of feeding after surgery in the elderly is called for.

Acute Pain and Adverse Outcomes. The same questions that dominate research in pain management in the general population apply to the elderly. However, in many ways, the questions are more pressing in the elderly because the elderly might receive the most potential harm as well as the greatest potential benefit from the treatment of postoperative pain. Because of ischemic heart disease, diminished pulmonary capacity, altered drug clearance, or increased drug sensitivity, the elderly patient is probably more vulnerable to the physiologic consequences of inadequate analgesia, as well as to the side effects related to analgesic use.

The perioperative period results in stress and inflammatory responses that peak after surgery when morbidity occurs. Therefore, efforts have been made to link the adequacy of analgesia with the magnitude of the stress response and cardiopulmonary complications. Both negative and positive conclusions have been reached.

In their review, Liu et al. (135) concluded that intensive analgesia with regional techniques had a limited effect on cardiopulmonary outcomes or the stress response and that pain and the stress response were not directly coupled (135). That said, studies in the highest-risk groups suggest that improvement can be seen in cardiovascular, respiratory, or neurologic outcome with intense analgesia by using regional techniques (108,118,136). As such, intensive pain management strategies might be indicated in high-risk elderly patients or in low-risk elderly patients undergoing high-risk surgery. The potential value of this approach is evident in the multicenter VA study of epidural analgesia (107). That large randomized investigation showed specific advantages to perioperative epidural analgesia in the aortic aneurysm subgroup of elderly abdominal surgery patients but showed no such advantages across the entire population of abdominal surgery patients. Because most investigations on postoperative analgesia have not been conducted in an elderly population, defining the circumstances under which epidural analgesia or any other pain management strategy can improve outcomes is a promising area for research in geriatric anesthesia.

In addition to the stress response typically associated with the sympathetic-adrenal axis, many types of surgery initiate a catabolic state. Although an inhibitory effect of analgesia on protein wasting has been suggested (137–139), a broader area for investigation might be postsurgical catabolism in the elderly. Better understanding of the relationship between preoperative nutritional status and postoperative catabolism, and interventions that might attenuate catabolism or facilitate the transition back to anabolism, would be of particular value for the elderly surgical patient.

Although the adequacy of postoperative analgesia does not appear to be an independent determinant of major outcomes in the general population of surgical patients, other postoperative analgesia issues require attention in the elderly. The relative benefit of patient-controlled analgesia (PCA) (140) versus an as-needed or scheduled analgesic administration may be of greater importance in the elderly surgical patient. Because of heterogeneity in the geriatric population, it is unlikely that fixed age-specific formulas for drug dosing will be identified. These considerations potentially make PCA analgesia an excellent choice. However, the side effect profile for PCA analgesics in the elderly has not been well established, and it has also been suggested that elderly patients may struggle with the technology. Similarly, the application of PCA for patients with altered mental status is problematic. Geriatric-relevant outcomes with PCA in the elderly must be further compared with fixed and as-needed dosing techniques, as well as with postoperative pain control by regional blockade.

The same might be true regarding the route of administration for analgesics. There are not sufficient data to identify a clear advantage or disadvantage to the use of the IV, epidural, or intrathecal routes for analgesic administration in the elderly. The elderly are unusually susceptible to drug interactions and have an increased incidence of respiratory depression, urinary retention, ileus, constipation, and postoperative falls. These are influenced by choices in postoperative analgesia and may differ by route of administration (141–143). As such, investigations into analgesic strategies for elderly surgical patients will need to not only determine the quality of analgesia, but also comprehensively examine the risks and benefits specific to that population. This approach is well illustrated in the study by Liu et al. (144), who compared analgesic drugs and route of administration to try to identify the analgesic program that achieved the best balance between analgesia, side effects, gastrointestinal recovery, and fulfillment of discharge criteria in colonic surgery patients. Although the study was

small and included a wide patient age range, it is an excellent model for the types of studies needed in geriatric patients.

In addition to further assessment of analgesics and mode of delivery, the use of analgesic adjuncts in postoperative pain management requires further investigation in elderly surgical patients. Drugs such as ketorolac, clonidine, gabapentin, dexmedetomidine, and cyclooxygenase-2 inhibitors have the potential to achieve adequate analgesia with smaller doses of opioids, potentially reducing side effects in the elderly.

A final reason why studies of acute pain management in the elderly are required is the influence that acute pain management may bear on rehabilitation and subsequently on functional status on discharge (145). This has been demonstrated with integrated analgesic programs after knee replacement (145–147) and colonic surgery (148). Research is required after other types of surgical procedures to determine whether facilitation of rehabilitation by acute pain management can improve other functional outcomes.

Another opportunity for research in postoperative care is related to polypharmacy and adverse drug events in the elderly. Elderly patients accumulate prescriptions over time, and there is a clear relationship between the number of drugs taken and the incidence of adverse drug-related events. This problem is compounded perioperatively.

The study by Cullen et al. (149) prospectively examined adverse drug events in hospitalized patients and found that the rate of preventable and potential adverse drug events was related to the number of drugs administered. A similar report of 4031 adult hospital admissions identified the incidence of adverse drug events, their preventability, and the classes of drugs that caused the most events. Analgesics were associated with the most adverse drug events (150) and were also the leading class of drug with preventable adverse drug events (Table 1). These results have particular bearing for the perioperative care of the elderly. The intersection of pain management and the incidence of preventable adverse events related to analgesics and sedatives places anesthesiologists squarely in a leadership role in this critical area.

Additionally, there is also a window of opportunity during hospitalization to review patient medications and look for combinations that may increase the risk of complications such as respiratory depression, aspiration, confusion, postural hypotension, urinary retention, and falls. The development of pharmacy and electronic drug databases to achieve this goal are rudimentary and will be more within the resources of hospitals than of community practitioners.

Delirium and Cognitive Decline. Postoperative delirium and/or cognitive decline affect 5%–50% of elderly patients (76,151–153). The onset of delirium, a fluctuating level of consciousness, typically presents on the first to third postoperative day, may be sustained for more than a week, and is associated with other medical complications, prolonged hospitalization, and decreased functional status on discharge (78,151,154–157). Much of the research has centered on the effect of regional versus general anesthesia in orthopedic surgery (80,81,114–117,158). Cognitive dysfunction, a deterioration of psychomotor capacities such as memory, central processing time, and acquisition of new information, is also common after surgery and has been well described in both cardiac and noncardiac surgical patients (159–162).

Table 1. Adverse Events by Class of Drug[a]

Drug class	Adverse drug events, No. (%) (n = 247)	Preventable adverse drug events, No. (%) (n = 70)
Analgesic	73 (30)	20 (29)
Antibiotic	59 (24)	6 (9)
Sedative	20 (8)	7 (10)
Antineoplastic	18 (7)	3 (4)
Cardiovascular	9 (4)	3 (4)
Anticoagulant	8 (3)	3 (4)
Antipsychotic	6 (2)	5 (7)
Diabete	5 (2)	4 (6)
Electrolyte	3 (1)	3 (4)
Other	46 (19)	16 (23)

[a] Modified with permission, JAMA 1995;274:29–34. Copyrighted 1995, American Medical Association.

The effect of anesthetics on postoperative delirium has been studied (81,114,117,163–165), and a leading hypothesis has been that offending drugs aggravate an age-associated central cholinergic insufficiency. However, review of the literature indicates that delirium is a syndrome that can be triggered by many different perioperative events, so no single cause is identifiable and no single intervention is likely to be successful.

In addition to being linked to narcotics, sedatives, and anticholinergics, delirium has been associated with urinary tract infection, pneumonia, hypoxia or hypercarbia, fever, blood loss, and electrolyte disturbances (151,152,154,166–168). Chronic patient factors such as preexisting frank or subclinical dementia, other organic brain disease, and vision and hearing loss are also predictors of postoperative delirium and cognitive decline (67,76,78,151,152,169,170). Finally, in the elderly patient it has been suggested that hospitalization, pain, sleep deprivation, sensory deprivation, and an unfamiliar environment may contribute to delirium (77,151,152,171,172).

Most of the research in the anesthesia literature has focused on the effect of anesthetics and analgesics only to find that anesthetic technique has little if any effect on the prevention of delirium. In contrast, studies such as those conducted by Inouye et al. (68) might

serve as a model for research in anesthesia (74,168–170,173–175). In elderly medical patients, Inouye et al. describe a multifactorial model for delirium that involves the interrelationship between a vulnerable patient and acute insults (168,173). Multivariate modeling identified four risk factors for developing hospitalization delirium: vision impairment, severe illness, preexisting cognitive impairment, and a blood urea nitrogen/creatinine ratio of ≥18 (173,176). Patients were then divided into low-, intermediate-, and high-risk groups depending on the number of risk factors, and the rates of delirium in these groups were 3%, 16%, and 32%, respectively (173) (Table 2). In low-, medium-, and high-risk groups, the rate of death or nursing home placement was 3%, 14%, and 26%, respectively (176).

Subsequently, Inouye et al. (174) determined the effect of interventions based on their predictive model. Four-hundred-twenty-six elderly medical patients in an intervention group were matched to an equal number in a "usual care" group. In the intervention group, risk factors for delirium were targeted for intervention. The treatment group had a 9.9% incidence of delirium, versus 15% in the usual care group (a 34% decline). Subdivision of patients into intermediate- or high-risk groups demonstrated that intervention reduced delirium in the intermediate-risk patients, but the reduction in delirium in the high-risk group was not statistically significant (174).

These studies also indicate that preoperative cognitive deficit is a strong predictor of the likelihood of delirium during the hospitalization (173). The same effect has been identified in surgical patients (76–78,177). This brings us back to the recurring observation that subclinical decrements in functional status may become evident during the perioperative period. These findings are extended by the observation that postoperative delirium or cognitive decline may be a harbinger of a potentially long-term cognitive dysfunction (159,178).

These types of data provide a compelling rationale to investigate the use of a simple, short mental status examination as part of the preoperative interview. After that, the incidence of preoperative cognitive impairment and its severity could be identified in populations of elderly patients undergoing different types of procedures. Research into the effectiveness of differing prevention strategies could follow. Those investigations could also examine whether reductions in delirium translate into reduced medical complications or improved functional status on discharge.

Table 2. Incidence of Delirium by Risk Index

Risk group	No. Factors	Delirium rate, by person (%)	RR
Low	0	5/125 (4)*	1.0
Intermediate	1–2	31/156 (20)*	5.0
High	≥3	11/31 (35)*	8.9

Each patient's risk group was determined by adding one point for each precipitating factor present: use of restraints, urinary catheter, more than three medications added, any iatrogenic evernt, and malnutrition.

RR = relative risk.

Performance of the predictive model in for delirium in medical patients in the validation cohort. Modified with permission: JAMA 1996;275:852–7 (Table 4).

* Chi-square overall = 24.8; $P < 0.001$; χ^2 trend = 24.8; $P < 0.001$.

Summary and Conclusions

Perioperative care of the geriatric patient is complex. Older patients are at increased risk for a host of complications, and it is probably easier to precipitate these complications than to prevent them. This precarious state is a function of decreased functional reserve, variable response to stress, and the number of comorbidities.

Nevertheless, we have learned a great deal that can guide future research. Rather than focus attention on the choice of anesthetic technique or on short-term outcomes, improvement in patient outcomes will be better served by studies that yield better risk stratification in the elderly. Pertinent patient risk factors will, to some extent, probably be surgery specific. Subsequently, it can be determined whether identified risk factors are amenable to therapy and whether such intervention improves the outcome. An essential element of both types of investigations will be a focus on preoperative functional status and on outcomes appropriate to the geriatric population rather than just major cardiopulmonary morbidity and mortality.

Outcome is determined by the interaction of patient factors and the challenges introduced by surgery. Surgical impact varies widely by type, so development of comprehensive care strategies for specific types of surgery common in the elderly is indicated. This focus is more likely to generate positive results and practical guidelines than pooling elderly patients undergoing differing types of surgery. Developing comprehensive clinical pathways specific to the care of the elderly patient undergoing specific types of surgeries is indicated. It is likely that these approaches would be defined and initiated by multidisciplinary care teams so that preoperative, intraoperative, and postoperative management could be integrated. This approach could serve as a foundation for developing comprehensive evidence-based geriatric perioperative care and might have particular value in including prevention of delirium and pneumonia, in pain management, and in improving functional status on discharge. In these investigations, the anesthesiologist has a unique role, because we contribute significantly to preoperative assessment and intraoperative and postoperative management for every patient undergoing every type of surgery.

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