ANESTHESIOLOGY CLINICS

Anesthesiology Clin
25 (2007) 75–90

Geriatric Trauma: Special Considerations in the Anesthetic Management of the Injured Elderly Patient

Michael C. Lewis, MD[a,*], Karim Abouelenin, MD[a], Miguel Paniagua, MD[b]

[a]*Department of Anesthesiology, Miller School of Medicine at the University of Miami, Miami, FL 33101, USA*

[b]*Miami GRECC, VA Medical Center, Department of Geriatrics, Miller School of Medicine at the University of Miami, Miami, FL 33125, USA*

Traumatic injury is the foremost cause of mortality in patients aged over 44 years [1]. At the end of the twentieth century, almost 20% of injuries occurred in the elderly population [2]. These patients are susceptible to a distinctive injury pattern. They respond differently to trauma, recover more slowly [3], and have higher morbidity and mortality [4]. It is not clear if these differences are due to increased comorbidity [4] or decreased physiologic reserve.

After traumatic injury, it is important that all interventions be evidence based. There are few prospective randomized controlled trials that focus on elderly issues, and within the published studies there is no uniform definition of the term "elderly." Therefore, many of the recommendations may not be applicable. Despite these limitations, this article aims to draw conclusions from the available literature. Where possible, it makes recommendations as to the optimal anesthetic management of elderly trauma patients.

Aging

Senescence results in a progressive decline in cellular function, resulting in a loss of organ performance. Cells lose their capacity to respond to injury

* Corresponding author. Department of Anesthesiology, Jackson Memorial Hospital, 1611 NW 12th Ave., Miami, FL 33136.

E-mail address: mclewis@med.miami.edu (M.C. Lewis).

doi:10.1016/j.atc.2006.11.002

and eventually die. Aging, therefore, is a progressive process depicted as maintenance of life with a diminishing capability for adjustment [5]. It is associated with impaired adaptive and homeostatic mechanisms, resulting in an increased susceptibility to the effects of stress. Function may seem to be unchanged, yet physiologic reserve diminishes. Any disruption of homeostasis that is well tolerated by younger adults might precipitate functional decline in the elderly population. The situation is further compounded by variable response to medications and comorbidity.

Definition: the geriatric trauma patient

Historically, the term "elderly" was applied to individuals over 65 years of age. However, aging is now viewed as a physiologic continuum rather than chronologic age.

It may be more useful to divide the geriatric population into "young old," which includes individuals between the ages of 65 and 80 years, and "Oldest-old," which includes individuals over 80 years of age. Geriatric trauma patients fare worse than their younger counterparts [6,7]. The prognosis in the octogenarian group is significantly worse.

Physiologic changes in the elderly population

Cardiac function declines by 50% between the ages of 20 and 80 years. This impaired cardiac function, paired with decreased sensitivity to catecholamines (and possibly overlaid with β-blocker therapy), complicates the management of the hemodynamically compromised older patient.

Above the age of 50 years, renal mass is lost, with a corresponding fall in glomerular filtration rate [8,9].

Respiratory function is compromised in the elderly population. There is an observed loss of the lung elastic recoil and significant reduction of the vital capacity. These changes result in dependence on diaphragmatic breathing, impaired mucociliary clearance of bacteria, and reduced ability to cough [10]. There is a disruption of the normal matching of ventilation and perfusion. Forced expiratory volume in 1 second, forced vital capacity, and peak expiratory flow rate are decreased [11]. Such changes in diffusion capacity alterations in ventilation–perfusion mismatch [12] and in closing volumes mean that there is a decrease in baseline arterial oxygen tension with age [13]. Alterations in compliance result in an increased work of breathing [14]. The combination of these factors means that there is an increased risk of respiratory failure in the elderly patient, resulting in a higher incidence of mechanical ventilation, [15] acute lung injury, and ventilation-associated pneumonia as a consequence of longer ICU stay and high morbidity.

There are age-related changes of endocrine function. The tissue responsiveness to thyroxin and its production is reduced with aging [16]. Secretion of cortisol does not seem to change with aging [17].

Functional reserve

When an organism maintains a steady state in the face of increased physiologic demand, it is said to demonstrate a good functional reserve. Fig. 1 illustrates this divergence between "baseline" and "stress" situations. Imbalance within the system therefore results in a breakdown of homeostatic compensation. A decline in functional reserve may in the elderly patient precipitate a serious decline in performance when the elderly patient is exposed to stress and increases the risk of age-related disease.

Because of decreasing functional reserve, the older patient is less able to preserve homeostasis in face of such a physical insult [18]. There is inconsistency in this decline in functional reserve. The variability is rooted within lifestyle choices, environmental factors, genetics, and the presence of age-related disease. Older trauma victims do not cope as well as younger adults [19,20]. Often, aggressive treatment is less likely to be received by the older patient [21]. Consequently, elderly trauma victims are less able to preserve sufficient perfusion of vital organs [22]. After injury, elderly patients are more likely to arrive in the emergency department in hypotensive shock and to be hypothermic. This decreased functional reserve contributes to the higher percentage of the geriatric trauma victims that appear in the early trauma mortality statistics. It affects infection-related deaths and multiple organ dysfunction syndromes.

Diminished reserve, manifested as comorbid disease states, seems to have a negative predictive value for outcome [23]. However, when aggressive treatment is initiated, the outcome difference between younger and older adult diminishes [24]. When there is an aggressive approach to management, age does not necessarily contribute to negative outcome [25].

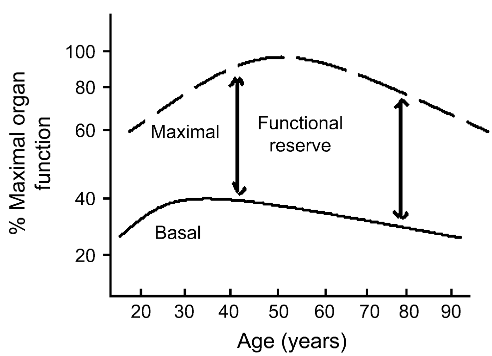

Fig. 1. The functional reserve is the difference between basal function (*solid line*) and maximal function (*broken line*). Even in healthy individuals, this functional reserve is reduced. (*From* Muravchick S. Geroanesthesia: principles for management of the elderly patient. St. Louis (MO): Mosby 1997; with permission.)

Mechanisms of injury

There is a higher risk of chest injuries in the elderly population [26]. Older drivers have a higher incidence of rib and sternal fractures [27]. Rib fractures or flail chest may sometimes occur in elderly persons without the significant underlying pulmonary contusion that would be anticipated in a younger patient [28]. There seem to be increases in fractures of the vertebrae, the hip, and the distal forearm, attributed to a high prevalence of osteoporosis [29].

In contrast to the younger adult trauma patient, the elderly victim is less likely to die as a direct result of their accident. Death is often associated with comorbidity, functional decline, and postoperative complications [30].

Dramatic accidents are not the most common reason why elderly patients present to the trauma unit. The commonest mechanism of injury is the fall [31,32]. Various factors predispose elderly persons to falls, such as unsteady gait, orthostatic hypotension, and slow reaction time [33]. Falls can lead to significant injuries [34]. It has been estimated that falls can account for over 50% of traumatic deaths [35]. Patients who have severe injuries despite a seemingly minor mechanism of injury are more likely to be older than 55 years of age [36], and the death rate is especially high in octogenarians [37].

Traffic accidents involving drivers or pedestrians are the second and third most common cause of injuries in the elderly population, respectively [31]. Underlying disease, decreases in hearing or vision, muscle weakness, and reduced reaction times [38] are contributing factors [39].

Thermal injuries occur more frequently in the elderly population. This increased risk could be attributable to a reduced sense of smell, impaired hearing or vision, or reduced mobility and reaction time. These injuries are inclined to be more serious in terms of surface area and depth [40]. The propensity to more severe thermal injury may be attributable to age-related alterations in skin morphology and diminished visual, olfactory, and auditory senses.

Elder mistreatment should be considered when evaluating the injured older patient. Investigations suggest that in excess of 2% of elders are abused or neglected [41,42].

Initial pre-hospital evaluation: triage and treatment

Limited physiologic reserve means that the prognosis of the elderly injured patient is much better when the patient is rapidly transported to a trauma center [43,44]. Despite this observation, there is a significant absence of rapid triage of elderly patients to established trauma centers

Which patients should receive aggressive therapy?

It is important to recognize early patients in whom aggressive additional resuscitation is futile. Measures of physiologic derangement may be used to identify such patients and differentiate them from those who might benefit from aggressive resuscitation strategies. It has been suggested that particular awareness is needed when triaging elderly trauma victims because their injuries may be hidden, thus putting them at risk for admission to a level of care that may be unsuitable given the degree of their injuries [45].

There is evidence of the predictive value on mortality of the Revised Trauma Score (Table 1). A specific numerical score predicting mortality has not been found [46]. One observer noted 100% mortality when the initial respiratory rate was less than 10 breaths per minute [47].

The adequacy of resuscitation may be estimated using the arterial base deficit. In the elderly patient, even a minor base deficit may have significant negative predictive value [48]. Base deficit may help identify a subgroup of patients that would possibly benefit from intensive resuscitative efforts.

The Injury Severity Score (ISS) is an anatomic scoring system (Table 2) that gives a global score for patients who have multiple injuries. It has been shown to be a strong predictor of mortality in geriatric patients [49]. The ISS has limited prognostic capabilities in geriatric trauma because of significant delays in obtaining the data to calculate the scores.

One modification of the ISS is the Geriatric Trauma Survival Score [50]. The Geriatric Trauma Survival Score uses the ISS, patient age, and the absence of cardiac symptoms or septic complications to predict outcome. It has not been widely shown to predict survival [51].

Injury assessment and resuscitation

The primary survey in the geriatric patient is no different from that in the younger adult.

Airway

The airway can be physically obstructed as a result of direct injury, edema, or foreign bodies. Patients may not be able to protect the airway if there is a decreased level of consciousness. Either case might necessitate endotracheal

Table 1
Determination of the Revised Trauma Score

Glasgow Coma Scale	Systolic blood pressure (mm Hg)	Respiratory rate	Coded value
13–15	>89	10–29	4
9–12	76–89	>29	3
6–8	50–75	6–9	2
4–5	1–49	1–5	1
3	0	0	0

The Revised Trauma Score is a physiologic scoring system. It is scored from the first set of data obtained. *Adapted from* Champion HR, Sacco WJ, Copes WS. A revision of the trauma score. J Trauma 1989;29(5):623–9.

Table 2
Determination of the Injury Severity Score

Region	Injury description	Abbreviated injury scale	Square of top three	Injury Severity Score
Head and neck	Cerebral bleed	4	16	—
Face	Facial lacerations	1	—	—
Chest	Flail chest	4	16	—
Abdomen	Ruptured spleen	5	25	—
Extremity	Fractured radius	2	—	—
External	No injury	0	0	57

The three most severely injured body regions have their score squared and added together to produce the Injury Severity Score. *Adapted from* Baker SP, O'Neill B, Haddon W, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187–96.

intubation. Orotracheal intubation under anesthesia with planned neuromuscular blockade and in-line cervical alignment remains the safest and most effective method for airway control in the severely injured patient [52].

Recommendations concerning the doses of anesthesia medications used to facilitate intubation are shown in Table 3. In the older adult, the doses of many of the sedative agents used to facilitate intubation may have to be further altered. Their pharmacokinetics could be altered due to the trauma [53] or to physiologic changes associated with aging [13,54,55].

To avoid hypotension in the elderly trauma patient, the doses of the etomidate [56], barbiturates [57], and benzodiazepines [58,59] need to be reduced. For example, an 80-year-old trauma patient needs less than half the amount of etomidate to reach the same EEG endpoint as a 22-year-old patient [56]. This reduction of blood pressure in the elderly patient is especially marked when the patient is hypovolemic. Ketamine is commonly used in the trauma scenario. In the geriatric patient, this drug has a reduced clearance and is expected to have a longer duration of action.

The opioids have an increased activity or alterations in pharmacokinetics in the elderly patient. A reduction in the dosage of morphine [60], alfentanil, fentanyl [61], and remifentanil [62] is recommended. The only exception to

Table 3
Dosage alteration for the anesthetic drugs used to facilitate intubation in the elderly patient

Class of medication	Change of dose in the elderly patient
Sedatives	Reduction of 50% of bolus dose
Depolarizing neuromuscular blocking agent (succinylcholine)	No reduction in bolus dose
Nondepolarizing neuromuscular blocking agents	No reduction in bolus dose
Opioids	Reduction of 50% of bolus dose

this rule is meperidine, for which no changes in clearance rate or terminal elimination half-time value have been shown [63]. However, due to its CNS-active toxic metabolite, normeperidine, its use is not advocated in elderly patients.

In the geriatric population, a reduction in physical activity theoretically should result in a reduction in sensitivity due to up-regulation to neuromuscular blockers. In contrast, augmented exercise increases sensitivity to neuromuscular-blocking drugs receptors [50]. Clinically, the doses of neuromuscular blockers are usually unchanged [64].

There are a number of considerations for the initial airway management of the geriatric patient [65]. Because of a widespread loss of all muscular and neural elements, laryngeal structures undergo a gradual deterioration in function. Older patients exhibit a decrease in protective airway reflexes [66]. Aspiration is more common, and planning is required for its prevention. The elderly patient may be edentulous. Alternatively, there may be poor dentition, making damage to the teeth more likely [67]. Loose-fitting dentures should be removed. Visualization of the glottis is more difficult if there is poor mouth opening and stiffening of the atlanto-occipital joint [68]. If a neck immobilizer has been placed, then visualization of the cords may be difficult.

Breathing

Assessment of ventilation, as with all trauma patients, is accomplished by the look, listen, and feel approach. Confirmation is obtained by capnography and oximetry. The presence of a semi-rigid neck collar with suspected cervical neck injuries does not affect ventilation [69].

Chest injuries, such as rib fractures and pulmonary contusion, are common. Pulmonary contusion is considered to be one of the most common blunt thoracic injuries. Noninvasive ventilation via a continuous positive airway pressure mask has been described in the literature for the management of hypoxemia caused by lung contusion and for other medical conditions [34]. This effect may serve as a pathophysiologic-directed therapy for hypoxemic patients who have blunt chest injury in whom endotracheal intubation is not required.

Circulation

Significant reductions in coronary blood flow can occur in the absence of known coronary artery disease [69]. The aging myocardium is also less able to respond to circulating catecholamines [52]. Therefore, the hypovolemic geriatric patient may not develop tachycardia in the presence of hypovolemia. Elderly patients may also be taking medications such as β-blockers that alter their heart rate response. Often, geriatric patients have hypertension; therefore, a normal or borderline blood pressure should be treated with suspicion.

The elderly trauma victim as compared with their younger counterpart may be less able to compensate for changing oxygen demands by increasing cardiac output. They may be dependent on a level of circulating hemoglobin that should be kept at adequate levels [19].

Geriatric patients do not handle hypovolemia well, nor do they tolerate fluid overload. The consensus opinion is that initial fluid administration should be with crystalloid. Initially, a fluid challenge of 1 or 2 L should be given gradually and with caution [70]. If there is no significant improvement in vital signs, then blood should be administered. Because of the geriatric patient's decreased cardiac reserve, invasive monitoring should be considered once the decision to transfuse blood is made.

Sclalea and colleagues [103] initiated a practice recommendation of placing a pulmonary artery catheter in selected geriatric trauma patients (ie, patients who had systolic blood pressure of <130 mm Hg, acidosis, multiple fractures, head injury, and motor–pedestrian mechanism of injury). Scalea also recommended a limited evaluation phase in the trauma unit, after which the patient should be transferred to the ICU. When this principle was used with a mean time to optimization of 2.2 hours, survival was improved from 7% to 53%. Although this study has not been repeated, it draws our attention to the importance of early invasive monitoring in the elderly trauma patient.

Monitoring

A low threshold for early invasive monitoring initiation is used in elderly patients. This is important for the optimization of O_2 delivery.

Elderly trauma patients with physiologic compromise, significant injury, high-risk mechanism of injury, uncertain cardiovascular status, or chronic cardiovascular or renal disease should undergo invasive hemodynamic monitoring using a pulmonary artery catheter. Such early invasive monitoring has been associated with improved survival in the geriatric trauma patient [69]. It has been argued that patients who have a normal echocardiogram and EKG do not need invasive monitoring [71]. Evidence suggests that when such routine echocardiograms are introduced, they do little to change management; rather, they delay surgery [72]. Noninvasive hemodynamic monitoring in critically ill patients using bioimpedance technology has been shown to be a reliable alternative to invasive thermodilution techniques in geriatric trauma patients [73]. Recent studies have demonstrated that invasive intraoperative hemodynamic monitoring with fluid challenges during repair of femoral fracture under general anesthesia shortens the time to being medically fit for discharge [74].

A possible algorithm for the hemodynamic invasive monitoring of such elderly trauma patients has been developed (Fig. 2) [70]. If trauma is mild, there are no signs of hypoperfusion, and there is no significant systemic disease. Standard American Society of Anesthesiologists (ASA)

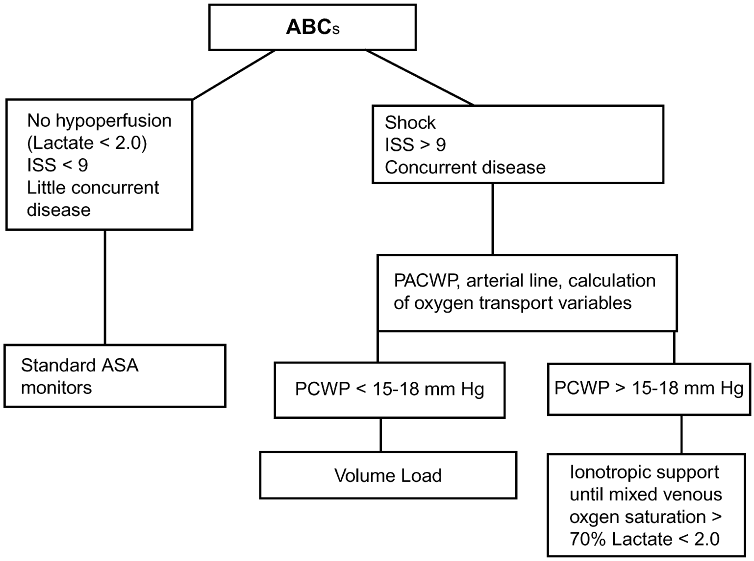

Fig. 2. An algorithm for the initial resuscitation of the elderly trauma victim. ISS, Injury Severity Score; PACWP, pulmonary artery capillary wedge pressure; PCWP, pulmonary capillary wedge pressure. The American Society of Anesthesiologists (ASA) has published minimal monitoring standards for patients undergoing general anesthesia. These standards call for monitoring of the patient's oxygenation (inspired gas and arterial saturation), ventilation (capnography), circulation (ECG, arterial blood pressure), and temperature (thermometer). (*Modified from* Santora TA, Schinco MA, Trooskin SZ. Management of TRAUMA in the elderly patient. Surg Clin North Am 1994;74;163–85; with permission.)

monitors would suffice. If the injury is greater than mild (ISS >9), if there are signs of shock or hypovolemia, and if the patient has significant systemic disease, an arterial line and pulmonary artery catheter (oximetry type preferably) should be inserted. Otherwise, oxygen transport variables need to be calculated. If the wedge pressure is low (<15 mm Hg), then a fluid bolus should be administered. If the wedge pressure is greater than 18 mm Hg, then inotropes are titrated to produce a mixed venous saturation of greater than 70% and a normal lactate level [75].

In studies of traumatic head injuries, the intermittent jugular bulb oxygen saturation monitoring did not significantly influence the management of severe head trauma. Its routine use in all patients seems inadvisable [76].

Hip fractures

Osteoporosis and tendency to fall increase the incidence of hip fractures, which is the most common cause of traumatic injury in geriatric patients, mainly in women. Hip fracture can occur as part of a multitrauma or as an isolated injury. Multitrama is associated with other bone and soft-tissue injuries, intra-abdominal and intrapelvic injuries, major blood loss, head and neck injuries, and other extremity injuries. Overall, an inability to return to a preinjury level of mobility results in precipitous functional decline, a loss of independence, quality of life reduction, and depression in older persons. There are data to suggest that outcome in these patients is superior when they are managed by a specialized multidisciplinary team [77].

Most data indicate that early operation is coupled with improved prognosis and enhanced health quality, even at the same day of injury [78]. Recent data suggest a 48-hour window to operate on patients [79,80]. Delaying surgery may increase mortality [81] or prolong hospitalization [82].

Early ambulation and daily physical therapy after hip fracture surgery should be encouraged. Delayed ambulation after hip fracture surgery is related to the development of new-onset delirium, postoperative pneumonia, and increased length of hospital stay [83].

There are no conclusive data concerning the advantage of regional versus general anesthetic techniques to facilitate surgery for a broken hip. Outcome studies have failed to show a difference between the techniques [84]. No difference has been shown in inpatient morbidity and mortality or in 1-year mortality rates between patients receiving general or spinal anesthesia. There is no significant difference in postoperative cognitive functioning between the two techniques [85]. In addition, comparing regional and general anesthesia, no differences were observed in long-term recovery of ambulatory ability or percent functional recovery after hip fracture [86,87]. This lack of difference has been reflected by a large meta-analysis looking at the elderly surgical population [88].

Head injuries

Elderly persons are at high risk for traumatic brain injury [49]. However, much of the evidence suffers from severe methodologic flaws. Our understanding of the management of such injuries has been improving steadily [89]. The adverse impact of serious head injury on early and delayed mortality has been reported [4,90]. Falls are the most common cause of head injuries in the elderly population, followed by pedestrian injuries [91]. There is a high incidence of intracranial bleeding associated with falls in elderly patients [92].

Age seems to be an independent predictor of poor outcome in patients with head injury [93]. There seems to be an increased mortality in older patients [94]. It has been reported that the mortality of patients with severe brain injury was around 38% for all age groups; however, among persons over 55 years of age, mortality is 80% [95].

A low score on the Glasgow Coma Scale (GCS) is associated with poor outcome in the elderly population [96]. The literature does not identify a specific admission GCS as being applicable as a basis for triage of such patients.

Alteration in orientation possibly points to injury of the central nervous system. Increased vascular vulnerability is characteristic of the aging brain. Subdural hematomas can result in changes in mental status, headache, disturbances in ambulation, or nonfocal neurologic findings. Elderly patients frequently suffer from coexisting medical problems and may take medications, such as anticoagulants, that could worsen head injuries [97].

A baseline level of consciousness should be ascertained. The GCS is a useful tool for such evaluation. Changes from the initial GCS score are important in following clinical progress. It seems reasonable to conclude that initial assertive treatment is warranted in all geriatric patients who have head injuries. Patients who do not respond to such efforts in a timely fashion probably will have poor outcomes, and continuation of such aggressive approaches should be reconsidered. The prognosis is favorable for those who respond to such initial intense efforts.

Many techniques of intubation and choices of drugs exist for safe endotracheal intubation of the patient who has traumatic brain injury. The best technique is the one performed by a proficient anesthesiologist. Oral intubation using direct laryngoscopy facilitated by intravenous induction agents and neuromuscular relaxants is the method of choice [98]. Cricoid pressure is used to prevent passive gastric regurgitation; however, it has been postulated that the application of cricoid pressure may aggravate potential cervical spine injuries [99]. Therefore, the risk of gastric regurgitation should be weighed against the chance of cervical injury when contemplating the Selick maneuver. The elderly population has a greater incidence of cervical spinal disease, which probably increases the risk of instability [100].

Sodium thiopental, etomidate hydrochloride, and propofol have been used to induce anesthesia before intubation. No single agent has been shown to be superior. Each decreases the systemic response to intubation, blunts Intracranial Pressure (ICP) changes, and decreases the cerebral metabolic rate for oxygen [101].

Inadequate fluid resuscitation is associated with poor neurologic outcome in patients who have head injury [102]. On the other hand, fluid overload should be avoided among elderly patients who have concurrent cardiac disease. It has been suggested that patients who have diffuse blunt trauma and closed-head injuries have evidence of impaired peripheral perfusion. This is true even when they are normotensive. In such patients, volume infusion and vasodilating inotropic support improve oxygen transport without increasing intracranial pressure [103].

Summary

Modern society is characterized as having an ever enlarging population of older adults. There are more elderly patients, and the average age of this group is increasing. The anesthetic management of surgery for the elderly trauma victim is more complicated than in younger adults. Evaluation of the physiologic status of the geriatric patient should take into account the variability of the changes associated with advancing age. These alterations occur between individuals and among different organ systems within an individual. In addition, changes in the occurrence and presentation of certain diseases differ. This increases the likelihood of multiple medical diagnoses and is the basis of reduced functional reserve.

A number of elderly persons are independent and have preserved lean body mass and cardiopulmonary function. They have physiologic responses similar to those of younger individuals. In these patients, the risks associated with surgical intervention are low. Conversely, elderly persons who have multiple illnesses and limited capacity suffer from cardiovascular and pulmonary disease and have high surgery-associated risks.

Because of these confounding variables, the potential benefits and the risks of any intervention are more difficult to assess in older persons. Making assumptions about physiologic status that are reasonable in younger patients may not be appropriate in older patients. Occasionally, in clearly identified patients, an early aggressive approach may prevent morbidity.

Several factors are critical for obtaining the best outcomes for the perioperative management of the elderly trauma patient:(1) careful preoperative evaluation and optimization; (2) minimization of perioperative stresses of hypothermia, hypoxemia, and pain; and (3) meticulous perioperative attention to avoid clinical complications from fluid and electrolyte balance and impaired cardiovascular and respiratory function. Care of the injured elderly patient requires thorough preoperative assessment and planning and the involvement of a multidisciplinary clinical team knowledgeable about and interested in the management of the elderly surgical patient [104]. With such an inclusive methodology, major surgeries can be tackled with low risk, a brief hospital stay, and a rapid return to full function as the goal of care [105].

References

[1] Max W, Rice DP, MacKenzie EJ. The lifetime cost of injury. Injury 1990;27:332–43.

[2] Sjogren H, Bjornstig U. Trauma in the elderly: the impact on the health care system. Scand J Prim Health Care 1991;9:203–7.

[3] Testa JA, Malec JF, Moessner AM, et al. Outcome after traumatic brain injury: effects of aging on recovery. Arch Phys Med Rehabil 2005;86:1815–23.

[4] McMahon DJ, Schwab CW, Kauder D. Comorbidity and the elderly trauma patient. World J Surg 1996;20:1113–9.

[5] Travis KW, Mihevc NT, Orkin FK, et al. Age and anesthetic practice: a regional perspective. J Clin Anesth 1999;11:175–186.

[6] Sklar DP, Demarest GB, McFeeley P. Increased pedestrian mortality among the elderly. Am J Emerg Med 1989;7:387–90.

[7] Johnson CL, Margulies DR, Kearney TJ, et al. Trauma in the elderly: an analysis of outcomes based on age. Am Surg 1994;60:899–902.

[8] Muhlberg W, Platt D. Age-dependent changes of the kidneys: pharmacological implications. Gerontology 1999;45:243–53.
[9] Buemi M, Nostro L, Aloisi C, et al. Kidney aging: from phenotype to genetics. Rejuvenation Res 2005;8:101–9.
[10] Janssens JP. Aging of the respiratory system: impact on pulmonary function tests and adaptation to exertion. Clin Chest Med 2005;26:469–84.
[11] Williams JM, Evans TC. Acute pulmonary disease in the aged. Clin Geriatr Med 1993;9: 527–45.
[12] Cardus J, Burgos F, Diaz O, et al. Increase in pulmonary ventilation-perfusion inequality with age in healthy individuals. Am J Respir Crit Care Med 1997;156:648–53.
[13] Nickalls RW, Mapleson WW. Age-related iso-MAC charts for isoflurane, sevoflurane and desflurane in man. Br J Anaesth 2003;91:170–4.
[14] Thompson LF. Failure to wean: exploring the influence of age-related pulmonary changes. Crit Care Nurs Clin North Am 1996;8:7–16.
[15] Chalfin DB. Outcome assessment in elderly patients with critical illness and respiratory failure. ClinChest Med 1993;14:583–9.
[16] Mooradian AD. Normal age-related changes in thyroid hormone economy. Clin Geriatr Med 1995;11:159–69.
[17] Barton RN, Horan MA, Clague JE, et al. The effect of aging on the metabolic clearance rate and distribution of cortisol in man. Arch Gerontol Geriatr 1999;29:95–105.
[18] Frankenfield D, Cooney RN, Smith JS, et al. Age-related differences in the metabolic response to injury. J Trauma 2000;48:49–56.
[19] Demarest GB, Osler TM, Clevenger FW. Injuries in the elderly: evaluation and initial response. Geriatrics 1990;45:36–8, 41–2.
[20] Scwab C, Shapiro M, Kauder D. Geriatric trauma: patterns, care and outcomes. In: Mattox K, Feliciano D, Moore E, editors. Trauma. New York: McGraw-Hill; 2000. p. 1099–113.
[21] Lane P, Sorondo B, Kelly JJ. Geriatric trauma patients-are they receiving trauma center care? Acad Emerg Med 2003;10:244–50.
[22] McKinley BA, Marvin RG, Cocanour CS, et al. Blunt trauma resuscitation: the old can respond. Arch Surg 2000;135:688–93.
[23] Gubler KD, Davis R, Koepsell T, et al. Long-term survival of elderly trauma patients. Arch Surg 1997;132:1010–4.
[24] DeMaria EJ, Kenney PR, Merriam MA, et al. Aggressive trauma care benefits the elderly. J Trauma 1987;27:1200–6.
[25] Shabot MM, Johnson CL. Outcome from critical care in the ''oldest old'' trauma patients. J Trauma 1995;39:254–9.
[26] Yee WY, Cameron PA, Bailey MJ. Road traffic injuries in the elderly. Emerg Med J 2006; 23:42–6.
[27] McCoy GF, Johnstone RA, Duthie RB. Injury to the elderly in road traffic accidents. J Trauma 1989;29:494–7.
[28] Allen JE, Schwab CW. Blunt chest trauma in the elderly. Am Surg 1985;51:697–700.
[29] Riggs BL, Melton LJ 3rd. Involutional osteoporosis. N Engl J Med 1986;26(314):1676–86.
[30] Morris JA Jr, MacKenzie EJ, Edelstein SL. The effect of preexisting conditions on mortality in trauma patients. JAMA 1990;11(263):1942–6.
[31] Pudelek B. Geriatric trauma: special needs for a special population. AACN Clin Issues 2002;13:61–72.
[32] Wofford JL, Moran WP, Heuser MD, et al. Emergency medical transport of the elderly: a population-based study. Am J Emerg Med 1995;13:297–300.
[33] McMahon DJ, Shapiro MB, Kauder DR. The injured elderly in the trauma intensive care unit. Surg Clin North Am 2000;80:1005–19.
[34] Hurst JM, DeHaven CB, Branson RD. Use of CPAP mask as the sole mode of ventilatory support in trauma patients with mild to moderate respiratory insufficiency. J Trauma 1985; 25:1065–8.

[35] Mosenthal AC, Livingston DH, Elcavage J, et al. Epidemiology and strategies for prevention. J Trauma 1995;38:753–6.
[36] Velmahos GC, Jindal A, Chan LS. "Insignificant" mechanism of injury: not to be taken lightly. J Am Coll Surg 2001;192:147–52.
[37] Lambert DA, Sattin RW. Death from falls, 1978-1984. MMWR 1998;37(SS-1):21–6.
[38] Ruhle R, Wolff H. Psychological aspects of traffic fitness of aging car drivers. Z Gesamte Hyg 1990;3:346–50.
[39] Sjogren H, Eriksson A, Ostrom M. Role of disease in initiating the crashes of fatally injured drivers. Accid Anal Prev 1996;28:307–14.
[40] Linn BS. Age differences in the severity and outcome of burns. J Am Geriatr Soc 1980;28: 118–23.
[41] Kennedy RD. Elder abuse and neglect: the experience, knowledge, and attitudes of primary care physicians. Fam Med 2005;37:481–5.
[42] Elder abuse and neglect. Council on Scientific Affairs. JAMA 1987;257:966–71.
[43] Finelli FC, Jonsson J, Champion HR, et al. A case control study for major trauma in geriatric patients. J Trauma 1989;29:541–8.
[44] Phillips S, Rond PC III, Kelly SM, et al. The failure of triage criteria to identify geriatric patients with trauma: results from the Florida Trauma Triage Study. J Trauma 1996;40:278–83.
[45] Scheetz LJ. Relationship of age, injury severity, injury type, comorbid conditions, level of care, and survival among older motor vehicle trauma patients. Res Nurs Health 2005;28: 198–209.
[46] Perdue PW, Watts DD, Kaufmann CR, et al. Differences in mortality between elderly and younger adult trauma patients: geriatric status increases risk of delayed death. J Trauma 1998;45:805–10.
[47] Knudson MM, Lieberman J, Morris JA Jr, et al. Mortality factors in geriatric blunt trauma patients. Arch Surg 1994;129:448–53.
[48] Davis JW, Kaups KL. Base deficit in the elderly: a marker of severe injury and death. J Trauma 1998;45:873–7.
[49] Tieves KS, Yang H, Layde PM. The epidemiology of traumatic brain injury in Wisconsin, 2001. WMJ 2005;104:22–5, 54.
[50] Martyn JA, White DA, Gronert GA, et al. Up and down regulation of skeletal muscle acetylcholine receptors. Anesthesiology 1992;76:822–43.
[51] Tornetta P III, Mostafavi H, Riina J, et al. Morbidity and mortality in elderly trauma patients. J Trauma 1999;46:702–6.
[52] Adnet F, Lapostolle F, Ricard-Hibon A, et al. Intubating trauma patients before reaching hospital—revisited. Crit Care 2001;5:290–1.
[53] Berkenstadt H, Mayan H, Segal E, et al. The pharmacokinetics of morphine and lidocaine in nine severe trauma patients. J Clin Anesth 1999;11:630–4.
[54] Eilers H, Niemann C. Clinically important drug interactions with intravenous anaesthetics in older patients. Drugs Aging 2003;20:969–80.
[55] Vuyk J. Pharmacodynamics in the elderly. Best Pract Res Clin Anaesthesiol 2003;17: 207–18.
[56] Arden JR, Holley FO, Stanski DR. Increased sensitivity to etomidate in the elderly: initial distribution versus altered brain response. Anesthesiology 1986;65:19–27.
[57] Homer TD, Stanski DR. The effect of increasing age on thiopental disposition and anesthetic requirement. Anesthesiology 1985;62:714–24.
[58] Reves JG, Fragen RJ, Vinik HR, et al. Midazolam: pharmacology and uses. Anesthesiology 1985;62:310–24.
[59] Smith MR, Bell GD, Quine MA, et al. Small bolus injections of intravenous midazolam for upper gastrointestinal endoscopy: a study of 788 consecutive cases. Br J Clin Pharmacol 1993;36:573–8.
[60] Kaiko RF, Wallenstein SL, Rogers AG, et al. Narcotics in the elderly. Med Clin North Am 1982;66:1079–89.

[61] Shafer SL. The pharmacology of anesthetic drugs in the elderly patients. Anesthesiol Clin North America 2000;18:1–29.
[62] Minto CF, Schnider TW, Egan TD, et al. Influence of age and gender on the pharmacokinetics and pharmacodynamics of remifentanil: I. Model development. Anesthesiology 1997;86:10–23.
[63] Herman RJ, McAllister CB, Branch RA, et al. Effects of age on meperidine disposition. Clin Pharmacol Ther 1985;37:19–24.
[64] Rupp SM, Castagnoli KP, Fisher DM, et al. Pancuronium and vecuronium pharmacokinetics and pharmacodynamics in younger and elderly adults. Anesthesiology 1987;67: 45–9.
[65] Milzman DP, Rothenhaus TC. Resuscitation of the geriatric patient. Emerg Med Clin North Am 1996;14:233–44.
[66] Pontoppidan H, Beecher HK. Progressive loss of protective reflexes in the airway with the advance of age. JAMA 1960;174:2209–13.
[67] Givol N, Gershtansky Y, Halamish-Shani T, et al. Perianesthetic dental injuries: analysis of incident reports. J Clin Anesth 2004;16:173–6.
[68] Benumof JL. Management of the difficult adult airway: with special emphasis on awake tracheal intubation. Anesthesiology 1991;75:1087–110.
[69] Scalea TM, Simon HM, Duncan AO, et al. Geriatric blunt multiple trauma: improved survival with early invasive monitoring. J Trauma 1990;30:129–34.
[70] Santora TA, Schinco MA, Trooskin SZ. Management of trauma in the elderly patient. Surg Clin North Am 1994;74:163–86.
[71] Hiatt JR, Yeatman LA Jr, Child JS. The value of echocardiography in blunt chest trauma. J Trauma 1988;28:914–22.
[72] Guryel E, Redfern DJ, Ricketts DM. Balancing priorities in the management of hip fractures: guidelines versus resources. Ann R Coll Surg Engl 2004;86:171–3.
[73] Brown CV, Shoemaker WC, Wo CC, et al. Is noninvasive hemodynamic monitoring appropriate for the elderly critically injured patient? J Trauma 2005;58:102–7.
[74] Venn R, Steele A, Richardson P, et al. Randomized controlled trial to investigate influence of the fluid challenge on duration of hospital stay and perioperative morbidity in patients with hip fractures. Br J Anaesth 2002;88:65–71.
[75] Shoemaker WC. Oxygen transport and oxygen metabolism in shock and critical illness: invasive and noninvasive monitoring of circulatory dysfunction and shock. Crit Care Clin 1996;12:939–69.
[76] Latronico N, Beindorf AE, Rasulo FA, et al. Limits of intermittent jugular bulb oxygen saturation monitoring in the management of severe head trauma patients. Neurosurgery 2001; 48:454–6.
[77] Khasraghi FA, Christmas C, Lee EJ, et al. Effectiveness of a multidisciplinary team approach to hip fracture management. J Surg Orthop Adv 2005;14:27–31.
[78] Casaletto JA, Gatt R. Post-operative mortality related to waiting time for hip fracture surgery. Injury 2004;35:114–20.
[79] Doruk H, Mas MR, Yildiz C, et al. The effect of the timing of hip fracture surgery on the activity of daily living and mortality in elderly. Arch Gerontol Geriatr 2004;39:179–85.
[80] Gdalevich M, Cohen D, Yosef D, et al. Morbidity and mortality after hip fracture: the impact of operative delay. Arch Orthop Trauma Surg 2004;124:334–40.
[81] Moran CG, Wenn RT, Sikand M, et al. Early mortality after hip fracture: is delay before surgery important? J Bone Joint Surg Am 2005;87:483–9.
[82] Siegmeth AW, Gurusamy K, Parker MJ. Delay to surgery prolongs hospital stay in patients with fractures of the proximal femur. J Bone Joint Surg Br 2005;87:1123–6.
[83] Kamel HK, Iqbal MA, Mogallapu R, et al. Time to ambulation after hip fracture surgery: relation to hospitalization outcomes. J Gerontol A Biol Sci Med Sci 2003;58:1042–5.
[84] O'Hara DA, Duff A, Berlin JA, et al. The effect of anesthetic technique on postoperative outcomes in hip fracture repair. Anesthesiology 2000;92:928–30.

[85] Berggren D, Gustafson Y, Eriksson B, et al. Postoperative confusion after anesthesia in elderly patients with femoral neck fractures. Anesth Analg 1987;66:497–504.

[86] Koval KJ, Aharonoff GB, Rosenberg AD, et al. Functional outcome after hip fracture: effect of general versus regional anesthesia. Clin Orthop Relat Res 1998;348:37–41.

[87] Gilbert TB, Hawkes WG, Hebel JR, et al. Spinal anesthesia versus general anesthesia for hip fracture repair: a longitudinal observation of 741 elderly patients during 2-year follow-up. Am J Orthop 2000;29:25–35.

[88] Parker MJ, Handoll HH, Griffiths R. Anaesthesia for hip fracture surgery in adults. Cochrane Database Syst Rev 2001;18:CD000521.

[89] Lillehei KO, Hoff JT. Advances in the management of closed head injury. Ann Emerg Med 1985;14:789–95.

[90] Champion HR, Copes WS, Buyer D, et al. Major trauma in geriatric patients. Am J Public Health 1989;79:1278–82.

[91] Pentland B, Hutton LS, Jones PA. Late mortality after head injury. J Neurol Neurosurg Psychiatry 2005;76:395–400.

[92] Amacher AL, Bybee DE. Toleration of head injury by the elderly. Neurosurgery 1987;20: 954–8.

[93] Mosenthal AC, Livingston DH, Lavery RF, et al. The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multicenter trial. J Trauma 2004;56:1042–8.

[94] Mosenthal AC, Lavery RF, Addis M, et al. Isolated traumatic brain injury: age is an independent predictor of mortality and early outcome. J Trauma 2002;52:907–11.

[95] Vollmer DG. Age and outcome following traumatic coma: why do older patients fare worse? Neurosurg 1991;75:S37–49.

[96] Reuter F. Traumatic intracranial hemorrhages in elderly people. Adv Neurosurg 1989;17: 43–8.

[97] Lehman LB. Head trauma in the elderly. Postgrad Med 1988;82:140–2.

[98] Alker GJ, Oh YS, Leslie EV, et al. Postmortem radiology of head and neck injuries in fatal traffic accidents. Radiology 1975;114:611–7.

[99] Donaldson WF 3rd, Towers JD, Doctor A, et al. A methodology to evaluate motion of the unstable spine during intubation techniques. Spine 1993;18:2020–3.

[100] Irvine DH, Foster JB, Newell DJ. Prevalence of cervical spondylosis in a general practice. Lancet 1965;22(14):1089–92.

[101] Unni VKN, Johnston RA, Young HSA, et al. Prevention of intracranial hypertension during laryngoscopy and endotracheal intubation. Br J Anaesth 1984;56:1219–23.

[102] Clifton GL, Miller ER, Choi SC, et al. Fluid thresholds and outcome from severe brain injury. Crit Care Med 2002;30:739–45.

[103] Scalea TM, Maltz S, Yelon J, et al. Resuscitation of multiple trauma and head injury: role of crystalloid fluids and inotropes. Crit Care Med 1994;22:1610–5.

[104] Callum K, Gray A, Hoile R, et al. Extremes of age. 1999 NCEPOD report. London: National Confidential Enquiry into Perioperative Deaths; 1999.

[105] Bardram L, Funch-Jensen P, Kehlet H. Rapid rehabilitation in elderly patients after laparoscopic colonic resection. Br J Surg 2000;87:1540–5.