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Trauma and Falls in the Elderly

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The United States' population is living longer than ever before. The average American life span has increased by almost 30 years in the past century, from 47 years in the early 1900s to 76 years in 2000. It is predicted that the number of people over the age of 85 will likely double by the year 2020, and that by 2050 people over age 64 will make up over 20% of the US population compared with 12% today [1].

Trauma is the fifth leading cause of death in patients over the age of 65 [2]. The elderly sustain a disproportionate share of fractures and serious injury, accounting for approximately 28% of deaths due to trauma while representing only 12% of the overall trauma population [3].

Trauma in the elderly poses special challenges. Physiologic changes impact morbidity and mortality. Geriatric patients have different injury patterns that impact care [4]. Older victims of trauma may have significant comorbid medical conditions and may be taking medications that can complicate injury and resuscitation.

Until the early 1980s, trauma research traditionally focused on the pediatric and young adult population, and few studies focused specifically on the elderly [5]. Since that time, a plethora of studies have been performed on geriatric trauma. Unfortunately, most have been retrospective trauma registry reviews. Few prospective and even fewer randomized controlled trials have been performed. Much of the literature on geriatric trauma remains to be written [6].

Although it is clear that morbidity and mortality from major trauma in the geriatric population is high, the vast majority of patients survive to hospital discharge, and a significant percentage return to their previous levels of function and activities of daily living [7–9].

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Every day, throughout the United States, patients are overtriaged to trauma canters, and undertriaged to local hospitals. The role of emergency physicians is paramount to the treatment of elderly victims of trauma. It is incumbent on all emergency physicians, regardless of venue, to take a consistent and thorough approach to the management of geriatric trauma patients. By identifying occult instability, resuscitating and stabilizing the victim, identifying important injuries and relevant comorbidities, and making an appropriate hospital disposition of transfer, emergency physicians can have a tremendous impact on the morbidity and mortality of geriatric trauma patients.

This article reviews the current literature on the management of elderly patients with trauma. We begin with a discussion of the physiologic changes of aging, and the impact of comorbidities and medications, that particularly influence management and outcome. We then turn to mechanisms of injury distinctive to geriatric trauma. We then discuss aspects particular to the resuscitation of geriatric trauma victims, focusing on pitfalls in evaluation and injury patterns unique to the geriatric patient. We also include a discussion of the evaluation and management of falls in the elderly, including assessment of fall risk.

The physiology of aging

It is clear that the effects of aging do not begin abruptly at 65 years of age. In a study of nearly 200,000 trauma patients, it was determined that mortality from severe trauma begins to increase at the age of 40 years [10]. For each 1-year increase in age over 65, the odds of dying after trauma increases by over 6% [11].

Aging can be defined as the normal, predictable, and irreversible changes of various organ systems over the passage of time that ultimately lead to death. Physiologic changes that occur with age affect patients in a number of ways, but generally results in a loss of functional reserve in most organ systems.

The effects of aging should not be confused with coexisting disease. Although distinguishing the effects of aging from the effects of disease may be difficult, the presence of comorbidity impacts the morbidity and mortality from trauma independent of the normal process of aging [2,12]. For example, it is clear that the bones of elderly patients are less able to withstand the mechanical forces of trauma, and that injuries occur with the transmission of less kinetic energy than in younger patients. This effect acts synergistically with the disease of osteoporosis, making the incidence of fractures in patients with osteoporosis significantly higher than in age-matched patients without the disease, and the incidence of fractures in elderly patients higher than in children or younger adults.

Cardiac functional reserve is diminished with age. Older patients have a lower cardiac output, decreased cardiac reserve, and are less likely to be

able to tolerate hemodynamic stress as well as younger patients. Aging of the electrical conducting system, or pharmacologic activity of beta-blockers or calcium blockers, result in a decrease heart rate response to catecholamines. It is well known that elderly patients can have a blunted inotropic and chronotropic response to trauma. Compensatory tachycardia, seen almost universally in young patients in response to hypovolemia or shock, is frequently absent. The less vigilant clinician can miss significant hemorrhage or easily underestimate severity of illness [13–19].

Superimposed on the normal effects of age on the heart may be the presence of heart failure, which may further diminish cardiac output; heart block, which can further blunt the rate response to stress; and coronary artery disease, which may manifest as demand ischemia during the stress of trauma. The risk of an acute cardiac event must be considered in every case of trauma in the elderly. An ECG is mandatory early in the workup.

Pulmonary changes with age include a loss of elasticity in the chest wall and lungs, leading to decreased mechanical compliance and an increase in baseline work of breathing. Alveolar loss and decreased diffusion capacity result in an age-dependent decline in arterial oxygen tension. As a result, a patient 80 years of age can be expected to have a baseline PaO_2 of between 78 and 92 mmHg. Mucociliary clearance declines with age leading to a concomitant decrease in the ability to clear the bronchial tree. Vital capacity, forced expiratory volume, and functional reserve are also compromised with age and need to be considered in management of ventilation [13].

Coexisting hepatic disease seems to impact mortality in trauma patients significantly [11]. Patients with end-stage liver disease and cirrhosis have a much higher mortality from the risk of bleeding and uncontrolled hemorrhage. Patients with end-stage renal disease also carry a high mortality after trauma. The number of functioning nephrons decreases with age, leading to a age-related decline in creatinine clearance that is nearly always underappreciated in elderly patients, as muscle mass (the primary source of creatinine) also decreases significantly with age. Decision making regarding contrast in diagnostic studied should take into account that a ''normal creatinine'' in an elderly patient may actually reflect a significant reduction in renal function.

A number of changes occur to the aging brain including an approximately 200-g decrease in brain weight, with a concomitant decrease in brain size. Stretching of the bridging vessels over the surface of the brain results in increased susceptibility to tearing under shear forces. In addition, there seems to be a significant, age-related decline in cerebrovascular autoregulation that may partially explain the worse outcomes seen in elderly patients with head injury [20].

The effects of aging on skin are multifactorial and result in a decrease in nearly all skin functions, most importantly reduced defenses against microorganisms and loss of temperature autoregulation. Age-related changes in wound healing occur across all four phases of wound healing: hemostasis, inflammation, proliferation, and resolution [21].

Glucose tolerance declines significantly with age [2]. As hyperglycemia has been associated with worse outcome in patients with traumatic brain injury, glycemic control has become an important goal in critically ill trauma patients. Identification of diabetes mellitus and hyperglycemia (and well as hypoglycemia) should occur early during resuscitation. Finger stick glucose should be considered mandatory during initial evaluation [22].

Pre-existing medications

A number of medications have been strongly associated with trauma in the elderly, including psychotropic medications (ie, antidepressants, neuroleptics, and sedatives) and antihypertensive (ie, beta-blockers, calcium blockers, diuretics, and in particular, multiple) medications. Less commonly implicated have been antiepileptic and glaucoma agents. Over 80% of patients evaluated after accidental fall are found to be on medications easily implicated in contributing to the fall [23]. The presence of four or more chronic medications seems to correlate well with an increasing risk of falls.

Critical to the emergency department (ED) management of trauma victims are medications that can impact outcome and management of the victim. Beta-blockers, as we have noted, may decrease the patient's compensatory hemodynamic response to hemorrhage or volume loss. Antihypertensive medications in general may make resuscitation more difficult. Consideration of antihypertensive overdose or other therapeutic misadventure should be considered in patients without a source of hemorrhage and persistent hypotension. However, hypotension should never be attributed to blood pressure medications until hemorrhage and ischemia have been ruled out. Most importantly, *the patient with a history of hypertension and a normal blood pressure is unstable until proven otherwise*.

Chronic therapy with oral warfarin (Coumadin), as well as other anticoagulants, aspirin, and newer antiplatelet agents has become commonplace. Use of warfarin is indicated in a number of medical conditions including venous thromboembolism, atrial fibrillation, stroke, and valve replacement [24]. The frequency of warfarin use increases with age. Unfortunately, the risk of major bleeding complications from warfarin use also increases with age (as well as increased international normalized ratio [INR]). Warfarin appears to worsen outcome from severe head injury, but has a less dramatic impact on mortality in patients without head injury [11,25–29]. Similarly, aspirin and clopidogrel (Plavix) seem to increase the risk of death in patients who sustain intracranial injury, although there is also a significant association with concomitant comorbid disease in patients prescribed antiplatelet agents [30].

Treatment options for patients taking warfarin who sustain injury need to be individualized and balanced between the need for warfarin therapy (ie, mechanical valve and risk of embolic stroke) and the need for immediate reversal (life-threatening hemorrhage, intracranial bleeding), nonurgent

reversal (preoperative), simple withdrawal of warfarin (subsequent risk of falls), or no change in therapy. For patients requiring immediate reversal in the ED, published guidelines suggest the administration of prothrombin complex concentrate, supplemented with 10 mg of vitamin K via slow intravenous (IV) infusion [31,32]. If prothrombin complex concentrate is unavailable, fresh frozen plasma is indicated. Repeat treatment may be necessary, depending on the result of subsequent INR measurements. For nonemergent reversal of warfarin, administering a single (1–2.5 mg) oral or parenteral dose of vitamin K may be considered, but should generally be made in conjunction with the patient's primary care or admitting physician [31,32].

Desmopressin, a synthetic vasopressin analog, has been shown to have hemostatic properties in patients taking aspirin. However, no controlled trials in trauma patients have been performed. Patients taking aspirin that suffer severe head injury can be treated with Desmopressin 15 μg/mL. However the efficacy of this may be limited [33]. The impact of preinjury warfarin or antiplatelet agents on considerations for neuroimaging is discussed below.

Mechanism of injury

In a study of prehospital data of trauma patients over age 70 presenting to the ED, the majority of injuries where due to falls (60.7%), followed by motor vehicle accidents (21.5%). Interestingly, the frequency of motor vehicle accidents declined for patients aged 90 years or older (3.4%). A small number of patients in the study had a suspected medical etiology as the reason for the trauma. The most common bodily site of injury was the head and face followed by the extremities [34]. Alcohol and other drugs may actually play an important role in contributing to geriatric trauma, especially falls and to a lesser extent motor vehicle collisions [35].

Falls

Numerous studies confirm that the most common reason for trauma in the elderly is due to falls [7,8,36–43]. Low-level falls (falls from a standing height) are the most common reason for injury in geriatric patients. Complications resulting from falls are the leading cause of death from injury in men and women older that age 65. The incidence of falls increases with age over 64 years and varies according to living status. Approximately 30% to 40% of community-dwelling seniors will sustain a significant fall in their lifetime. Approximately 50% of individuals living in a long-term care facility will sustain a fall, and this percentage climbs to 60% if there has been a fall within the previous year [8,36–39].

Injuries sustained by geriatric patients from falls tend to be more severe than the injuries sustained by younger patients from similar falls. Injuries to the head, pelvis, and lower extremities are extremely common. Although elderly patients account for less than 15% of trauma admissions due to falls,

they account for half of deaths due to falls. Overall mortality is about 11% [44]. High-level falls (>15 feet) in the elderly are less common, but carry a mortality approaching 25% [45]. Increased morbidity is associated with increased disability, hospital admissions, and inpatient length of stay.

Major risk factors for falls include; older age, female gender, history of a previous fall, lower extremity weakness, balance difficulties, psychotropic drug use, and arthritis. Cognitive impairment "discovered" after injury may actually predate the index visit, and may contribute to the risk of falls [43]. Table 1 lists contributing factors to injuries in elderly patients. Particular etiologies to consider include vision impairment, medications, chronic medical conditions such as Parkinson's disease or osteoarthritis, environmental hazards, acute medical conditions such as syncope, transient ischemic attacks, neoplastic malignancies, metabolic derangements, infection, and anemia. Multiple risk factors for falls significantly increases the risk for subsequent falls. In one study, patients with four or more established risks for falls had a 78% risk of subsequent fall, compared with 27% in patients with zero or one risk factor [8].

When evaluating a geriatric patient who has fallen, all aspects of the incident should be reviewed. Complications of prolonged immobility such as rhabdomyolisis, dehydration, and infection need to be considered. Was the fall due to an environmental factor (rug, stairs, uneven ground, and so forth), acute or chronic medical conditions, trauma, or substance abuse? Can the patient function on the same level as before the fall? Can the patient ambulate, take care of their personal needs and manage at home?

Table 1
Contributing factors to injuries in elderly patients.

Chronic medical conditions	Environmental factors	Acute medical conditions	Other
• Osteoarthritis • Osteoporosis • CVA • Ischemic heart disease • Anemia • DM • HTN • Gait and balance disturbances • Visual impairment • Depression • Polypharmacy • Parkinson's disease • Dementia	• Rugs • Lighting • Stairs • Bathtubs/showers • Footwear • Uneven ground • Weather • Walking aids	• Syncope • Dysrhythmias • CVA, TIA • Acute MI • Seizure • Acute renal failure • Infection • Hypoglycemia • AAA • New medications • Dehydration • Acute fractures • Self inflicted injury	• Older age • Female gender • Alcohol and drug use • Elder abuse

Abbreviations: AAA, abdominal aortic aneurysm; CVA, cerebral vascular accident; DM, diabetes mellitus; HTN, hypertension; MI, myocardial infarct; TIA, transient ischemic attack.

Adapted from Sattin RW. Falls among older persons a public health perspective. Annu Rev Public Health 1992;13:489–508.

Fear of falling can inhibit social and functional status. Consider what additional resources or assistance are necessary to assure a safe discharge. This assessment can be difficult and time consuming. Involvement of family members, primary care physician, visiting nurse, or social worker can help in certain situations. Geriatrics consultation or case management in the ED can help address the issues involved in the safe discharge of geriatric trauma patients from the ED. Transfer to a skilled nursing or rehab facility may be appropriate.

Motor vehicle collisions

Although a significant amount of research has been done on falls in the elderly, there is only a modest amount of published research on elderly patients involved in motor vehicle crashes. The pathophysiology of aging and the presence of acute and chronic medical conditions that affect vision, reflexes, balance and cognition, and place elderly persons at high risk for involvement in motor vehicle crashes.

It is reasonable to expect that motor vehicle trauma involving elderly patients will continue to climb over the coming decades as the US population ages. Elderly patients have an increased severity of injuries from motor vehicle collisions when compared with nonelderly. However, the pattern of injury for geriatric patients in motor vehicular trauma appears quite similar to the pattern of injury for younger patients, except for an increased incidence (11%) of sternal fractures from seatbelts in patients over 65 years of age, compared with an incidence of 1.5% in the under 65 age category [46].

Pedestrians struck by automobiles

Pedestrians injured by automobiles represent some of the most seriously injured patients in trauma. The elderly are at particular risk for being struck as pedestrians, and make up a significant percentage of pedestrians who have been struck by a motor vehicle [46,47]. Slow ambulation, impaired reflexes, misjudgment, and visual, auditory, and gait impairment appear to be involved, as elderly patients are frequently struck within marked crosswalks or walk directly into the path of an oncoming vehicle.

Sklar and colleagues specifically looked at elderly pedestrians who had been struck by a motor vehicle and found a significantly increased mortality rate. Fatal injuries tended to be from severe head injury or major vascular damage, with the majority of deaths occurring at the scene or in the ED. Once hospitalized, patients died from complications of prolonged ventilation and infection [47]. Patients struck by cars sustain twice as many lower extremity injuries as their younger counterparts. Recent data reveals that age plays a tremendous role in severity of injury in pedestrians struck. Injuries to the brain, spine, and thorax, as well as skeletal injuries increase dramatically with age, although injuries to the abdomen do not. Mortality is greater than 25% in patients struck as pedestrians over the age of 65 [48].

Burns

Elderly patients constitute approximately 13% of all patients admitted to burn units. Total body surface area burned, mortality, and hospital length of stay are all higher in the elderly [49–51]. Physiologic changes associated with aging, acute and chronic medical conditions, and social isolation are factors that increase the morbidity and mortality from burns in the geriatric population.

In a study of life expectancy and living status of elderly patients surviving burn injury, overall in hospital mortality approached 50%, and mortality was 100% in patients over the age of 60 who had sustained a body surface area burn of 50% or greater [49]. As with other forms of trauma, burn treatment in the elderly is complicated by coexisting disease and impaired functional reserve. Despite increased morbidity and mortality associated with burns in the elderly population, no data is available suggesting changes in initial burn treatment protocols other than taking into consideration underlying medical conditions that may require additional care. However, liberal transfer to a burn unit is recommended, especially in patients with significant coexisting medical condition [52].

Accidental hypothermia

Geriatric patients are at an increased risk for accidental hypothermia [53–55]. Acute and chronic medical conditions predispose the elderly to hypothermia, especially when ambient temperatures are low. Dementia can result in a patient getting lost in cold weather with inadequate protective clothing. Financial limitations may lead to insufficient heating of the home, and ultimately to homelessness.

Older patients have a lower basal metabolic rate, and can have problems maintaining core body temperature when the ambient air temperature drops. Medical conditions that predispose to hypothermia include hypoglycemia, hypothyroidism, hypopituitarism, hypoaldosteronism, sepsis, and substance abuse [56]. Acute medical etiologies for hypothermia should be considered. A cerebrovascular accident or fall can result in an elderly patient remaining in a cold house or room for a prolonged period of time. Frequently, it may be difficult to determine on initial evaluation if the patient fell and then became hypothermic, or had some precipitating event that made them hypothermic resulting in a fall.

Initial treatment of the hypothermic geriatric patient follows the same guidelines for hypothermia in general. There is little direct research on the treatment of older hypothermic patients. Several studies examining cardiopulmonary bypass for severe hypothermia list age over 64 as a relative contraindication to bypass, but these studies excluded older patients without explanation.

Geriatric patients presenting to the ED with mild to moderate hypothermia are not uncommon. We recommend a low threshold to admit to observe

these patients for complications such as renal failure, infection, dehydration, pulmonary edema, cardiac stress, compartment syndrome, pancreatitis, coagulopathy, electrolyte abnormalities, and rhabdomyolisis. With little or no data on how to specifically treat the older patient with hypothermia it is important to be mindful of baseline medical problems that could complicate therapy and to address any acute medical issues that may have led to the episode. Most cases of accidental hypothermia are preventable. Taking the time to address behavioral and social issues may prevent repeat presentation to the ED.

Elder abuse and neglect

Like all forms of abuse and neglect, elder abuse is prevalent, insidious, and underreported. This issue is difficult to study, and there is very little data available on incidence, outcome, morbidity, or mortality. According to the National Elder Abuse Incidence Study, nearly 450,000 persons over age 60 experienced some form of domestic abuse, although only 16% of these cases are reported [57]. Risk factors for abuse include female gender, age >80, and physical and mental frailty. Risk factors pertaining to the perpetrator include being related to the victim (often an adult child), age younger then the injured, financial dependence on the victim, substance abuse, and prior history of violence.

Evaluation of all geriatric injury victims in the ED should include an assessment for signs and symptoms of abuse. Bruises in multiple stages of healing, unexplained fractures, untreated injuries, sign of neglect such as dehydration, malnutrition, and bedsores are important clues to the possibility of abuse or neglect, and should trigger further inquiry as to whether elder patients are victims of violence or other forms of abuse. When a clinician suspects abuse (or a patient reports abuse), it is the duty of the physician to protect the patient, treat injuries, and report the case to the proper authorities such as the police or elder services. Reporting laws exist, but differ from state to state. The reader is referred to a complete review of elder abuse elsewhere in this volume.

Management of the geriatric trauma victim

Prehospital care

It is a difficult task for the emergency physician to determine if the geriatric patient will be safe returning to the home environment. Information gathered by Emergency Medical Services (EMS) is invaluable to ED providers in assessing the elderly trauma victim. Particular attention should be paid to the social environment and home situation. The elderly may be reluctant or unable to provide accurate information regarding their home life, and deny inability to care for themselves. Even a loss of driving privileges or independent living means a loss if autonomy.

A number of questions should be asked of prehospital providers. Does the patient live alone? Does it appear that the patient is unable to care for him or herself? Does it appear as if the patient has been on the ground for a prolonged period of time? Is there evidence of substance abuse? What medications are present and does it appear that the patient has been compliant? Is there a cane or wheelchair that the patient uses? Is the home a fall hazard (rugs, stairs, poor lighting) or a safe place for the elderly patient to live? Concerns expressed by prehospital providers over the safety of a patient living individually should be highly respected, and essentially seal a decision to admit the patient, transfer the patient to a skilled facility, or trigger prompt follow up for a comprehensive geriatric assessment.

Triage

Studies show that patients who sustain serious injury are best managed in a trauma center. Development of a statewide trauma system led to improved survival for geriatric trauma patients [58]. Standard triage criteria for trauma patients include age >55 as an important, although not absolute, determinant of trauma center disposition in injured patients [52]. At least one study advocates trauma team activation for all patients over age 75 [59]. Some argue that triage of isolated injuries (ie, hip fractures) to trauma centers overburdens the trauma system, while others support the concept of a team approach to all geriatric trauma [60]. Once admitted to a trauma center, trauma surgeons direct the patient's care, where management of coexisting medical issues and comprehensive evaluation of potential medical etiologies for the injury may be inconsistent [61]. Currently, many seriously injured patients, and most patients with less serious injury, will not be taken to a trauma center.

Injury scoring systems, including the injury severity score (ISS) have been examined in an attempt to better triage patients with major trauma. Studies in geriatric patients have been mixed. A case–control study of major trauma in geriatric patients found that the currently employed ISS, if age adjusted, performs adequately as an indicator of outcome for the older trauma patient [62]. In another study, ISS was evaluated in elderly patients and not found to accurately predict survival [63]. This was thought to be due in part to the fact that ISS does not consider the impact of pre-existing disease. The validity of the ISS for geriatric patients involved in motor vehicle collisions is still at issue. McCoy and colleagues [46] suggested a weighted scoring system, but this is yet to be developed and validated.

Initial resuscitation

The initial resuscitation of the geriatric trauma victim should be guided by standard protocols, always keeping in mind that standard hemodynamic parameters, especially heart rate, are inadequate to determine the stability of geriatric patients. Patients who appear stable should undergo aggressive

testing to uncover occult instability or injury. Arterial blood gases should be considered mandatory because they may reveal an increased base deficit, or an elevated serum lactate concentration, which are harbingers of occult hypovolemia or impending shock. *While an increased base deficit is clearly a marker of serious illness, a normal base deficit does not rule out serious injury or risk of death in elderly patients* [64]. Patients who exhibit any evidence of impaired perfusion should undergo aggressive monitoring and resuscitation, as this has clearly been shown to improve outcome [19,65]. In the absence of a pulmonary artery catheter, a central venous catheter and serial arterial blood gases (looking at the base deficit) or serum lactate levels are suggested to guide therapy [66]. Noninvasive hemodynamic monitoring using bioimpedance technology has been gaining acceptance as a substitute for pulmonary artery catheterization, and has been shown in the elderly trauma patients to be reliable [67]. A second determination of either serum lactate or base deficit, drawn between 30 to 45 minutes after arrival, should be strongly considered in all geriatric patients who remain in the ED. Persistently high results should alert the clinician to ongoing hemorrhage, inadequate resuscitation, or other complications such as compartment syndrome. The elderly are at increased risk for the development of hypothermia during resuscitation, and diligence should be exercised in maintaining core temperature using external warming devices [68].

Evaluation of the initial ABCs in geriatric trauma patients include a number of important considerations. The elderly have decreased airway reflexes, and expeditious and deliberate management of the airway should be considered to prevent aspiration. Because the ventilatory response to hypoxia and hypercarbia are blunted in the elderly, occult respiratory insufficiency is common. Analysis of pH and arterial carbon dioxide tension is essential.

Anatomically, the geriatric airway can be difficult to manage. Mouth opening may be impaired. Coupled with the need to maintain in-line stabilization of the spine, kyphosis, or impaired mobility in a cleared cervical spine, laryngosopy may be difficult. Pharmacologic therapy for rapid sequence intubation in the geriatric patient also merits special consideration. Doses of nearly all sedatives, including barbiturates, benzodiazepines, and etomidate, should be reduced in the elderly to avoid hypotension. Doses of lidocaine and opiates, frequently used as premedication before intubation of patients suffering head injury, should also be reduced. Priming or administration of a defasciculating dose of a nondepolarizing neuromuscular blocker may abolish respirations prematurely, resulting in apnea with inadequate relaxation. Doses of neuromuscular blocking agents should not be reduced [17].

Patterns of injury

Elderly trauma patients clearly have different patterns of injury. Such knowledge should aid the clinician in diagnosing injuries, and determining severity of illness.

Central nervous system

Multiple investigators have recommended liberal use of computed tomography for elderly people. Case reports and case series have shown that intracranial hemorrhage can result in elderly patients who sustain minor head trauma (no loss of consciousness) and who are neurologically intact on arrival to the ED [69]. This incidence, while small, is further increased if the patient is taking warfarin and perhaps other anticoagulants or antiplatelet agents [70,71]. In a subgroup analysis of the NEXUS derivation study, 12.5% of patients over 65 were found to have significant intracranial injury, versus 7.9% of patients under 65. Furthermore, elderly patients sustaining minor head injury had a high risk of significant intracranial injury despite no evidence of significant skull fracture, neurologic deficit, or altered level of consciousness [72]. Liberal use of CT is warranted in this population until better clinical decision rules are available.

Spine

Elderly patient undergoing radiography of the cervical spine after trauma have at least twice the likelihood of cervical spine fracture than younger patients [73]. Interestingly, elderly patients who fall from low heights are at significantly increased risk of injury between the occiput and C-2, while patients in motor vehicle collisions and high falls are more likely to injure lower cervical vertebrae. Injuries to the cervical spine at multiple levels are common [74].

In the Canadian C-spine rule, age greater than 65 was used as exclusion criteria, essentially mandating cervical spine imaging in all geriatric trauma patients [75]. In contrast, the NEXUS clinical decision rule *has* been validated in a cohort of geriatric patients. The NEXUS investigators estimate that application of the decision rule could reduce the need for cervical spine imaging by 14%. Of note, 15% of injured geriatric patients were considered intoxicated at time of evaluation [73].

Given the high incidence of injuries to the atlantoaxial (C1–C2) complex, a quite justifiable strategy is to CT the cervical spine of all elderly patients requiring CT of the head. Some centers have advocated CT of C1–C2 in all patients undergoing head CT for trauma, regardless of indications for imaging the cervical spine. As CT of the cervical spine has recently been found to be far superior to plain radiography for detecting fractures, and CT of the brain is likely be indicated in nearly all elderly patients with trauma, CT should probably be considered the primary imaging modality of the cervical spine in most elderly patients, especially those over the age of 75 [74].

Cervical spondylosis predisposes to a syndrome of spinal cord injury in the absence of bony abnormality not uncommon in geriatric trauma patients. Mechanism for this phenomenon has been attributed to narrowing of the spinal canal, making the spinal cord more susceptible to compression when the neck is hyperextended, resulting in either a central cord or

Brown-Séquard like syndrome [76]. Cases of spinal cord injury without bony injury frequently mandate emergent MRI to rule out acute disc herniation requiring decompression and to further delineate other causes of cord injury.

Rib fractures and other thoracic injuries

Rib fractures are both an important injury in and of themselves, and a marker of injury severity in the multiply injured geriatric patient. Elderly patients with rib fractures have nearly twice the mortality as younger victims, despite a lower ISS and higher Glasgow coma scale (GCS). In addition, mortality rises significantly with the number of rib fractures, from 12% in patients sustaining one to two fractures, to nearly 40% in patients with seven or more fractures. Pulmonary complications including respiratory failure, pneumonia, and pleural effusion are more common in the elderly. Even the presence of a single rib fracture in the elderly carries significant morbidity and mortality [77,78].

Abdominal trauma

The abdomen is one region that is injured at a rate surprisingly similar to that of younger persons. The spleen is smaller in size from involution and apparently less prone to injury. Unfortunately, when solid organ injury is present, nonoperative management of spleen or liver injury has been challenging. Extreme age was once considered an absolute contraindication to nonoperative management of blunt solid organ injury. However, recent data suggest that age alone is not a contraindication to nonoperative management, and an expanded number of patients can now safely be observed [79].

Abdominal examination is traditionally considered less reliable in elderly patients, as evidenced by the lack of sensitivity for surgical disease in nontraumatic conditions [2]. Liberal use of abdominal CT after trauma should be considered in all geriatric trauma patients.

Musculoskeletal system

Fractures of the hip are the second most common (after wrist) fractures in elderly patients who sustain injures after a fall [23]. Patients sustaining isolated hip fracture have similar injury severity scores, and a similar incidence of severe complications, as the trauma population in general [60]. Despite this, most patients with isolated hip fracture in the United States are seen primarily by an emergency physician and admitted to either an orthopedist or to the patient's primary care physician. Although this practice has recently been questioned, it remains to be investigated whether outcome can be improved by triage of patients with isolated hip fractures directly to trauma centers, transfer of patients from community hospital EDs to trauma centers, or by the development of specialized hip fracture care centers [80].

A common presentation in the elderly is the persistence of hip pain despite negative radiographs. Such patients have a significant incidence of occult fracture. In a study of patients presenting to the ED with hip pain and negative plain films, 4.4% were diagnosed with fracture [81]. Over 90% of patients were over 65 years of age. MRI is superior to CT for the detection of fracture, and is more likely to reveal pathology not seen on CT. Fractures of the acetabulum can also easily missed on plain radiographs, particularly after falls. Periprosthetic fractures are relatively rare, but carry a high rate of complications including infection and nonunion [3].

Vertebral fractures in elderly patients are common, even after minor or unapparent trauma. The prevalence of vertebral fractures in the general population increases dramatically with age. Patients present with pain at the level of fracture, and may or may not complain of radicular symptoms. Three types of fractures are common: anterior wedge, biconcave, and crush deformities. All elderly patients who present with back pain should undergo radiographs to evaluate for fracture. Even in the presence of negative radiographs, fracture may still be present. MRI or delayed bone scanning may be employed [82].

Fractures of the pelvis carry tremendous morbidity in elderly patients. In one study of elderly ED patients, pubic rami fractures were the most common (56%), followed by acetabular fractures (19%) and ischium fractures (11%). Multiple fractures were present in over half of patients, and mortality was nearly four times higher than in nongeriatric patients [83]. In studies of major trauma patients, pelvic fractures in the elderly patients are more likely to hemorrhage and undergo angiography [84]. Elderly patients are far more likely to suffer lateral compression fractures, as opposed to anterior compression fractures, are more likely to require transfusion, and are far more likely to die. Mortality in patients suffering pelvic fracture has been reported between 12% and 21% [84,85].

Spontaneous osteoporotic fractures of the pelvis, also known as sacral insufficiency fractures, are a rare and infrequently diagnosed cause of low back, hip, and leg pain. Patients may present after minimal or minor trauma with symptoms suggestive of cauda equina syndrome and marked sacral tenderness. Plain radiographs are frequently normal. CT or MRI of the lumbosacral spine may be required to make the diagnosis [86,87].

Disposition, aftercare care, and outcome

Nearly all geriatric patients who sustain multiple injuries will need to be admitted. Geriatric patients involved in serious trauma have high admission rates to intensive care and correspondingly high morbidity and mortality rates [88]. Most deaths occur in the first 24 hours of admission and survivors suffer a significant decline in function [63,64,88]. Geriatric trauma patients have longer hospital stays, incur higher overall hospital charges, and require

longer periods of rehabilitation [18,89,90]. These patients also have a higher rate of complications, leading to worse outcomes [91]. Functional outcome after blunt trauma is predictably worse with increasing age, but outcomes between patients 65 to 97 years and patients over 80 years are remarkably similar [92]. Recovery from injury can be prolonged, but with aggressive management over 90% of patients survive and many can return home [93]. Prolonged intensive care unit stay is not associated with an unfavorable long-term outcome [94].

Although no prospective randomized trial examining the outcome of transfer versus no transfer for geriatric trauma patients has been performed, evidence strongly suggests that multiply injured geriatric trauma patients are likely best served in a trauma center [95,96]. Patients requiring general surgical or neurosurgical intensive care or burn care should be transferred once best attempts to stabilize the victim have occurred. Patients requiring repeat operation or particular orthopedic or other surgical expertise should also be considered for transfer. Lengthy attempts at defining all injuries in the initial receiving hospital are not warranted if they will not significantly change management or will delay transfer for definitive care of more life-threatening injuries. Unfortunately, studies done by referring hospitals are frequently repeated at the receiving facility, increasing the costs of care [97].

Selected patients sustaining isolated injures (usually after falls) may be considered candidates for discharge from the ED. Patients who presenting after a fall who report recurrent falls, have an abnormal mental status, or exhibit gait instability upon evaluation are poor candidates for discharge, and require a falls assessment by a geriatric specialist or team [98]. Patients with lower extremity injuries are particularly high risk. Interestingly, assist devices such as canes and walkers have not been shown to reduce the risk of falls [98].

Comprehensive geriatric assessment has become the ''gold standard'' of care for at risk elderly, and has been shown to reduce the rate of hospital admission, reduce repeat ED visits, and improve outcomes in patients discharged from the ED [99]. A clinical prediction rule developed to assess fall risk in the elderly has shown that mental impairment (confusion, disorientation, or agitation), toileting difficulties, vision problems, and difficulty with transfer or mobility accurately predict falls in hospitalized patients [100]. Presence of these in the ED likely puts the patient at substantial risk for subsequent falls.

Summary

As the US population ages the geriatric population grows. Trauma in the elderly is responsible for a significant number of visits to EDs and will continue to increase. Knowledge of the physiologic changes associated with aging, the impact of coexistent acute and chronic medical conditions, and an

understanding of the unique patterns of injury in geriatric trauma patients is critical to maximizing outcome.

Older patients tend to injure themselves most often after falls. Even falls from standing can result in significant fractures and head injury. Geriatric trauma victims demand aggressive management, a high index of suspicion for occult instability, and a low threshold for laboratory and radiographic investigation to delineate injuries.

Ultimately, trauma in the elderly should be addressed not just in the ED and hospital, but also from a public health perspective with emphasis on services and prevention. Research that addresses the different presentations, injury patterns, predictors of morbidity and mortality, and public health research on prevention will help further enlighten emergency physicians on how to best treat geriatric trauma patients to help them maintain high functional status. Much research remains to be done [101].

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