ELSEVIER
SAUNDERS

EMERGENCY
MEDICINE
CLINICS OF
NORTH AMERICA

Emerg Med Clin N Am 25 (2007) 837–860

Geriatric Trauma

David W. Callaway, MD*, Richard Wolfe, MD

Department of Emergency Medicine, Beth Israel Deaconess Medical Center, One Deaconess Road, W/CC-2, Boston, MA 02215, USA

The growth of the elderly population has greatly exceeded that of the remainder of the population. From 1900 to 1994, the elderly experienced an 11-fold increase, whereas the rest of the population only grew threefold [1]. Elderly patients today have an increased risk for trauma from an increasingly active life style and from impaired motor and cognitive functions. The elderly require far less mechanism to produce injuries. For all of these reasons the dramatic growth experienced in the number and severity of geriatric trauma patients can be expected to continue.

The elderly often require greater health care resources than younger patients who have similar injuries. Assessing the cost/benefit ratios of aggressive testing and interventions can be much more difficult in this group. Subsequent quality of life is also a key factor in decision making. Aggressive care and resuscitation have a dramatic effect in improving outcome in these patients. Because they are more challenging in underlying risk and occult presentations and because they benefit from resuscitation, they actually deserve a more aggressive approach than younger patients who have similar mechanism during their initial emergency management.

Triage

Advanced age clearly correlates with elevated mortality in trauma [2–4]. The largest trial evaluating the relationship between age and trauma mortality, the MTOS study, demonstrated that patients older than 65 years of age had elevated mortality across matched Injury Severity Score (ISS), mechanism of trauma, and body region injured [3]. Although age correlates with both early (<24 hours) and late (>24 hours) mortality across the geriatric trauma population, no literature clearly delineates a specific age above which trauma predicts increased in-hospital mortality [5]. Most studies on

* Corresponding author.
E-mail address: dcallawa@bidmc.harvard.edu (D.W. Callaway).

0733-8627/07/$ - see front matter
doi:10.1016/j.emc.2007.06.005

age and mortality are retrospective and may be affected by institutional biases toward or away from aggressive care in the elderly. With aggressive resuscitation, some studies suggest that up to 85% of elderly trauma patients return to independent living [5]. Advanced age should therefore heighten a physician's concern and prompt more aggressive care; it should not be used as a triage tool to limit care. Despite these recommendations and observations, studies indicate that undertriage of elderly trauma patients occurs twice as frequently as with younger patients [6,7].

In triaging the trauma patient, the physicians must balance the benefits of medical or surgical intervention with prognosis, resource use, and patient wishes. In the elderly, universally higher mortality, preexisting medical conditions, and a paucity of randomized prospective control trials complicate the triage process. Further, traditional triage tools, such as mechanism of trauma and vital signs, may be misleading in the elderly trauma patient. Physicians cannot use injury mechanism to reliably triage patients because the elderly are particularly susceptible to significant trauma from low-energy mechanisms. For example, 30% of the population older than 65 fall each year—the most common mechanism of trauma in the elderly. More than 6% of these falls result in fractures and 10% to 30% result in significant trauma [8] with a mortality rate approaching 7% [9].

Trauma severity scores seem to correlate with mortality in the elderly [5]. In the emergency department, the two most useful scores are the Trauma Score (TS) and Revised Trauma Score (RTS). The TS assesses blood pressure, respiratory rate, respiratory effort, Glasgow Coma Score (GCS), and capillary refill to produce a minimum score of zero and maximum score of 16. The RTS is similar, but does not account for respiratory effort or capillary refill (scores 0–8). Although studies are mixed, the RTS and TS seem to be useful tools in the triage of elderly trauma patients. Several studies demonstrated a universal mortality for elderly patients who had TS less than 7 to 9 [10,11]. These studies suggested an inverse relationship between TS or RTS and mortality, with patients having a TS from 7 to 14 benefiting most from aggressive resuscitation (Table 1). These studies also demonstrated that each component of the TS or RTS independently predicts mortality. For example, in Knudson's study [10] the geriatric trauma patient who had a respiratory rate less than 10 beats per minute (bpm) had

Table 1
Trauma score predicts mortality

Trauma score	Mortality
15–16	5%
12–14	25%
<12	65%

Data from Knudson MM, Lieberman J, Morris J, et al. Mortality factors in geriatric blunt trauma patients. Arch Surg 1994;129:448.

a 100% mortality. The ISS also seems to predict mortality in the elderly [12,13]. Within each category (ie, mild, moderate, and severe) the elderly demonstrated higher mortality than younger patients, with the most dramatic disparity in the moderately injured (ISS 16–24) who had a mortality of 30%, five times that of the younger cohort [3,10]. Unfortunately, the ISS may not represent the full potential for mortality in elderly trauma patients and its use in the emergency department is limited by a lack of timely availability of critical score components.

The exact relationship between TS, RTS, ISS, and mortality in the geriatric trauma patient is debated. These scoring systems represent clinical decision-making tools that can assist the physician in the initial trauma assessment. Geriatric trauma patients are extremely susceptible to adverse outcome from even minor trauma. The clinician's pretest probability for significant occult injury should be high. The most appropriate triage approach seems to use a combination of TS and RTS, clinical impression, age, and physiologic parameters to quickly classify patients as "unstable" or "apparently stable." The apparently stable patients are the most challenging and warrant exhaustive investigation to ensure a lack of occult pathology.

The American College of Surgeons currently recommends that emergency medical services transport trauma patients older than 55 years to a designated trauma center regardless of apparent injury severity [14]. Automatic trauma team activation should be considered for trauma patients older than 75 years regardless of mechanism or prehospital physiologic status [15].

Assessment and resuscitation

Several unique considerations are relevant during the primary and secondary survey of the elderly trauma patient. Physicians should be aware of the basic physiologic and anatomic change associated with aging and the potentially complicating role of medications and prosthetic devices. The principles of advanced trauma life support remain vital guidelines during the initial assessment and treatment. Of critical importance is prompt, aggressive resuscitation in the unstable elderly trauma patient and expedient directed evaluation of the apparently stable patient [16].

Attention to vital signs is particularly important in the elderly. Although abnormal vitals signs clearly warrant further investigation and direct resuscitation, normal vital signs should not necessarily reassure the physician. A normal blood pressure for a younger patient can constitute frank hypotension in an elderly patient who has a hypertensive history. Vital sign trends are critical in the severely injured elderly trauma patient. Nursing staff should to obtain and track vital signs, reporting any changes during the emergency department course. On arrival intravenous access should be obtained, supplemental oxygen given, and the patient should be placed on a cardiac monitor.

Airway

Supplemental oxygen should be placed on all elderly trauma patients. This practice provides the needed oxygen reserves if rapid sequence intubation is needed and contributes to cellular oxygenation. Early airway adjuncts, such as nasopharyngeal and oropharyngeal airways, are useful with the obtunded trauma patient. Elderly often have friable nasal mucosa and care should be taken when using the nasal passage for airway support or gastric decompression. Nasal hemorrhage from vigorous tube insertion can result in hemorrhage that is difficult to control and may complicate further airway management. Ventilation with a bag-valve mask can be complicated by an edentulous airway. The oral cavity should always be examined and poorly fitting or loose dental appliances should be removed (well-fitting dentures should be left in place when using bag-valve mask but must be removed before attempts at intubation).

Endotracheal intubation should be considered early in patients who have demonstrable signs of shock, significant chest trauma, or mental status changes [14]. Securing the airway in the elderly trauma patient can be challenging. Loss of the kyphotic curve, spondylolysis, arthritis, and spinal canal stenosis decrease cervical spine mobility. Inability to hyperextend the neck limits adequate visualization of the vocal cords. In addition to limiting range of motion, age-related arthritic and osteoporotic changes increase the incidence of cervical spine injury during instrumentation [17]. Maintenance of in-line stabilization is critical, but further impedes visualization of landmarks and placement of the endotracheal tube. Microstomia from systemic sclerosis and temporomandibular joint arthritis may limit access to the oral cavity and mandate use of a smaller laryngoscopic blade. Finally, delicate pharyngeal tissue in the elderly is more susceptible to trauma with subsequent bleeding that can obscure visualization of the vocal cords. The physician must take great care when inserting the laryngoscope blade to avoid traumatizing the soft palate and posterior pharynx.

Rapid sequence induction medication doses often require adjusting in the elderly trauma patient (Table 2). Relative contraindications to succinylcholine, such as hyperkalemia and prolonged immobility, are more frequent in the elderly patient. If uncertain, rocuronium or another nondepolarizing neuromuscular agent can be substituted. Priming doses of nondepolarizing agents should be avoided given the significant risk for completely abolishing airway and ventilatory reflexes [18,19]. Age-related decline in renal clearance and hepatic function increases sensitivity to opioids, benzodiazepines, and sedatives, such as etomidate. Resultant hypotension is the primary adverse outcome. The adrenal axis remains largely intact in the elderly and the potential transient adrenal suppression from etomidate is unlikely to have

Table 2
Rapid sequence induction medications and suggested dose adjustments

Medication	Adjustment
Succinylcholine 1.5 mg/kg IV	No change
Etomidate 0.1–0.2 mg/kg IV	Decreased from 0.3 mg/kg IV
Versed	Decrease 20%–40%
Fentanyl	Decrease 20%–40%
Ketamine	Should be avoided secondary to cardiac effects

Abbreviation: IV, intravenous.

clinically significant adverse effects [20]. In general, these medications are safe and appropriate at reduced doses.

Breathing

Aging has a myriad of effects on pulmonary function. Primarily, these changes can be classified as anatomic changes that increase susceptibility to trauma and physiologic changes that diminish protective responses to injury. Osteoporosis decreases rib durability and increases incidence of rib fractures. These changes create a brittle chest wall that is highly susceptible to rib fracture, sternal fracture, and pulmonary contusions even from seemingly low-energy trauma. Weakened respiratory muscles and degenerative changes decrease chest wall compliance and diminish maximum inspiratory and expiratory force by up to 50% [19]. Baseline age-related reductions in vital capacity, functional residual capacity and forced expiratory volume limit the elderly patient's ability to compensate for these injuries and dramatically increases mortality compared with younger patients. Increased splinting leads to hypoventilation, atelectasis, and subsequent pneumonia. As a result, apparently minor chest injuries frequently result in significant thoracic complications and patient morbidity.

Rib fractures and flail chest result in significantly higher morbidity and mortality in the elderly. Elderly blunt trauma patients also seem more susceptible to sternal fractures [21]. Physical examination findings, such as paradoxical chest wall movement, chest wall tenderness, crepitus, or ecchymosis, should prompt immediate action. The elderly have blunted responses to hypoxia, hypercarbia (response to hypoxia and hypercarbia declines by 50% and 40%, respectively, in the elderly), and acidosis that may delay the onset of clinically apparent signs of impending distress. Arterial blood gas measurements are therefore also an important component of the trauma assessment in geriatric patients.

Circulation

Elderly patients are particularly susceptible to the untoward effects of shock. Catecholamine insensitivity, atherosclerosis, myocyte fibrosis, and conduction abnormalities attenuate the elderly patient's chronotropic response to hypovolemia. Common medications, such as beta blockers and calcium channel blockers, can further limit the normal tachycardic response to shock. Baseline hypertension is more frequent in the elderly patient; thus normal blood pressure readings may actually indicate significant hypovolemia in the elderly patient. Resuscitation with intravenous fluid or blood should not be delayed during the assessment of the unstable patient.

The first critical step is to quickly identify and control life-threatening bleeding. External bleeding is usually obvious. Internal bleeding must be rapidly diagnosed in the elderly. As in most blunt trauma patients, the abdomen is a frequent culprit in hemorrhagic shock in the elderly. The general indications for Focused Assessment with Sonography for Trauma (FAST) and diagnostic peritoneal lavage (DPL) are similar in elderly trauma patients. In hemodynamically unstable patients, the FAST has a reported sensitivity of 90% to 98% and specificity of 99.7% for detecting clinically significant hemoperitoneum [22,23]. In particular, the FAST examination has sensitivities of 98% for detecting hemoperitoneum associated with grade III or greater liver injuries [24]. In hemodynamically stable trauma patients, ultrasound may lack sensitivity for detecting small amounts (less than 400 mL) of intraperitoneal fluid.

Patients who have hypotension and a positive FAST examination require prompt laparotomy [25]. In patients who have hypotension and an initially negative FAST, further evaluation is indicated, including either DPL or frequent repeated FAST examinations. Secondary or serial examinations dramatically increase the sensitivity and negative predictive value of the FAST [26].

Disability and exposure

Poor nutrition, loss of lean muscle mass, microvascular changes, and blunted hypothalamic function increase the elderly trauma patient's risk for hypothermia and pressure sores. Hypothermia drastically increases mortality in the hemorrhaging trauma patient. Rectal temperature should be obtained on major trauma patients. External rewarming with forced air warming systems (eg, Bair Hugger warming unit), heating blankets, and increased ambient temperature can decrease rates of hypothermia-induced coagulopathy. Additionally, intravenous fluid and blood products should be warmed by standard protocols. All efforts should be made to quickly clear the spine and remove patients from the hard backboard. Several orthopedic and wound-management studies have shown that in the elderly, the pathologic process of pressure sores begins early in the hospital course [27]. Pressure sores increase hospital length of stay, patient morbidity, and subsequent mortality. Action taken in the emergency department could thus significantly reduce length of stay, hospitalization costs, and patient morbidity.

In the emergency department, the patient's hemodynamic status determines the depth of the secondary examination. In the unstable patient, the physician should perform a rapid secondary survey that focuses on the neurologic examination. Three key components are GCS, pupil responsiveness, and gross motor examination. GCS predicts mortality and may influence treatment or disposition decisions [28]. Although the literature does not support a specific GCS on which to make triage decisions, the elderly have uniformly poor outcomes with scores less than 8 [29,30]. Altered pupil response and motor function may raise suspicions of intracranial hemorrhage that requires intracranial pressure monitoring before other operative intervention. Glaucoma, prior cataract surgery, and systemic medications can confuse the geriatric ophthalmologic examination.

Diagnostic imaging

Chest radiography

Chest radiographs are a standard component of nearly all trauma resuscitation protocols and are useful for rapid identification of life-threatening conditions, such as tension pneumothoraces. Plain film chest radiography fails to identify up to 50% of rib fractures, however, and has significantly lower sensitivity for aortic dissection [31,32]. In the elderly trauma patient, these limitations carry obvious clinical significance. Multidetector CT (MDCT) is superior to plain films for detecting rib fractures and concomitant torso injuries. Chest radiographs are useful in the unstable patient. MDCT should generally be considered the imaging modality of choice, however, in the elderly patient who has torso trauma.

Pelvic radiography

Several studies suggest a diminishing role for a routine plain radiograph of the pelvis in the alert, hemodynamically stable blunt trauma patient [33,34]. When clinical decision rules that identify low-risk patients (ie, no altered mental status, no pelvic pain or tenderness, no intoxication, and absence of distracting injury) are applied to stable patients, physical examination has a sensitivity of 98% for all pelvic fractures and 100% for clinically significant injuries [34]. In contrast, physical examination alone misses up to 20% of significant pelvic fractures in unstable patients [35]. Similar guidelines seem reasonable in the elderly trauma patient. Unstable patients should have routine pelvic plain films between the primary and secondary survey to rule out major pelvic fractures. In the stable patient, plain films may be useful to identify hip fractures in the polytrauma patient. A thorough clinical examination should suffice, however, even in the elderly [36].

Computed tomography torso

Computed tomography is a highly sensitive and specific diagnostic tool and is the primary mode of evaluation for most elderly abdominal trauma victims. The threshold to use CT in elderly victims of blunt abdominal trauma should be low.

The CT torso allows accurate assessment of the aorta, heart, bowel, pulmonary parenchyma, solid viscera, chest wall, pelvis, and spine. In adult blunt trauma patients, administration of oral contrast is rarely necessary on initial examination [37]. Oral contrast delays imaging and disposition of the patient while adding only minimal clinically relevant information on the general trauma patient. Noncontrast CT accurately detects pulmonary contusions, rib fractures, and significant pericardial effusions and has sensitivity and specificity up to 82% and 99% for detecting bowel or mesenteric injuries that require surgical repair [37].

The administration of intravenous contrast does provide useful clinical information. CT with intravenous (IV) contrast can delineate aortic injuries, reliably identify and grade solid organ injury, and further delineate injuries to the bowel and mesentery. The American Association for the Surgery of Trauma classification system for solid organ injury has been shown to correlate relatively well with mortality and the need for operative intervention [38]. Abnormal vascular patterns on CT (ie, contrast extravasation or contrast blush) correlate highly with the need for operative intervention or angiographic embolization of splenic and hepatic injuries. Contrast ''blush'' often corresponds to pseudoaneurysms of the splenic artery or its branches. The natural history of the lesions is not well studied, but may relate to delayed bleeding and subsequent failure of nonoperative management (NOM) [39]. Contrast extravasation is more vague and represents any pooling of contrast material outside of the splenic parenchyma. Active contrast extravasation has been shown to predict failure of NOM of splenic and hepatic injuries [40]. Recent evidence suggests that delayed-phase CT scans may better differentiate active hemorrhage from contained vascular leakage in adult solid organ injuries [41].

Intravenous contrast is not without risk. Preexisting renal insufficiency, diabetes mellitus, dehydration, hypotension, heart failure, and age greater than 75 years are well-identified risk factors for contrast-induced nephropathy (CIN) [42]. CIN is defined as an acute increase in serum creatinine of greater than 25% [43]. The elderly trauma patient is at particularly high risk for developing CIN. Strategies to reduce the incidence of CIN include extracellular volume expansion, premedication with bicarbonate or *N*-acetylcysteine, minimizing the dose of contrast media, using low-osmolar nonionic contrast media, stopping the intake of nephrotoxic drugs, and avoiding short intervals between procedures [44]. Ultimately, the clinician must weigh the risks and benefits of using intravenous contrast.

Computed tomography of the torso has the added advantage of allowing three-dimensional reconstruction imaging of the thoracic and lumbar spine. The incidence of vertebral fractures increases with age. Osteoporosis and calcific changes to supporting ligaments increase bone fragility and decrease the energy required to produce fractures. The clinician must have high clinical suspicion of vertebral fractures in all elderly trauma patients, especially those who have apparently minor injuries. All patients who have pain, tenderness, palpable deformity, or neurologic deficit should have imaging of the entire spine given high rates of polytrauma. Physical examination is notoriously inaccurate in identifying vertebral fractures [45,46]. In the asymptomatic patient, plain film radiography may be considered, but is often limited by normal age-related changes in the spine.

CT, especially spiral CT, is the imaging modality of choice for evaluation of the spine in the elderly trauma patient. Sensitivity and specificity of CT scans for thoracolumbar fractures are 100% and 97%, respectively, with a negative predictive value (NPV) of 100% [46,47]. Plain film radiographs are approximately 70% sensitive and 100% specific with NPV rates of 92% [46]. Admission torso CT with reconstructions is rapid and accurate and provides other critical information in the polytrauma patient (eg, evaluation of the aorta, solid organs, retroperitoneum, and so forth). The speed of CT evaluation is an additional advantage. Several studies have shown that CT-based protocols decrease patient manipulation, reduce per-patient cost, and improve time to definitive diagnosis.

Cranial computed tomography

Despite lower Glasgow outcome scale, functional independence measures, and longer rehabilitation for the elderly, some studies estimate that 82% of elderly patients hospitalized with traumatic brain injury (TBI) return to independent living if properly treated [48]. Early diagnosis and treatment of significant injuries is therefore critical. Multiple studies show that clinical variables are insufficient to reliably predict all cases of significant intracranial lesions following mild or minor head trauma in the elderly trauma patient [49]. Although loss of consciousness has a strong positive predictive value (PPV) for identifying clinically relevant intracranial hemorrhage in elderly patients taking Coumadin, most data suggest that normal GCS and physical examination cannot reliably exclude significant intracranial pathology in the elderly trauma patients who has even minor head trauma [50]. All patients older than 65 years who have closed head injury are at high risk for neurosurgical intervention (Canadian CT Head Rule [CCHR] and New Orleans Criteria [NOC]) [51,52]. Most studies support the liberal use of CT in the evaluation of elderly trauma patients who have closed head injuries as cost effective and clinically appropriate [53].

There is some debate in the literature concerning the evaluation of mild or minor head trauma in the elderly patient. Currently, there are no validated clinical pathways for identifying elderly TBI patients who can be safely managed without cranial CT. The two largest studies examining cranial CT in minor head injuries, the NOC and CCHR, categorized elderly patients as high risk and therefore excluded them from the algorithm. Other studies confirm the relationship between age and increased rates of TBI.

Gittleman and colleagues [54] reported that adult patients who had head trauma and a GCS of less than 15 were 42 times more likely to have abnormal cranial CT than younger patients. Similarly, Stein and Ross reported a 40% abnormal CT rate in adult patients who had closed head injury and GCS less than 13. In one recent study of geriatric patients who had mild head injury, 14% of patients had evidence of injury on cranial CT and one fifth of these required neurosurgical intervention [50].

Management

The elderly have increased mortality across all categories of the trimodal death curve: immediate (ie, at the scene), early (ie, within the first 24–48 hours), and delayed (ie, after 48–72 hours). Aggressive resuscitation, liberal radiographic examination, and early intensive monitoring or operative intervention are essential for reducing early mortality in the elderly trauma patient. Preventing delayed complications of trauma, such as cardiovascular compromise, sepsis, pneumonia, and multiorgan failure, is critical. Elderly trauma patients have reported in-hospital complication rates of 33%, compared with 19% for younger patients [10]. Cardiovascular events (23%) and pneumonia (22%) are the most common and most clinically significant. Prevention of these delayed complications begins in the emergency department.

Resuscitation

Elderly trauma patients have increased mortality for given ISS, RTS, and GCS than younger cohorts. Shock and occult hypoperfusion (OH) reliably predict mortality in the elderly trauma patient [10,55]. Two retrospective studies showed that in elderly blunt trauma a systolic blood pressure less than 90 mm Hg was associated with mortality rates of 82% to 100% [10,11]. Unfortunately, preexisting conditions can obscure the diagnosis of these entities and complicate resuscitation efforts. Congestive heart failure, coronary artery disease (CAD), and renal insufficiency commonly result in baseline fluid overload, further complicating the clinical picture.

Patients in florid shock should undergo aggressive resuscitation with IV fluid or blood and the cause of the shock should be identified. Crystalloid is the suggested initial resuscitation fluid for volume repletion in traumatic shock [56]. No convincing evidence exists to recommend either normal saline (NS) or lactated ringers (LR) as superior to the other. In large volume resuscitation, especially in patients who have impaired renal function, NS can theoretically result in hyperchloremic metabolic acidosis, worsening the shock state. Conversely, the calcium in LR may overwhelm the citrate in stored packed red blood cells (PRBC) and result in clotting during transfusion. A recent meta-analysis demonstrated that colloids do not have a significant beneficial effect in trauma resuscitation but do present a major additional cost. Most authors recommend 1 to 2 L of crystalloid be administered initially. A reasonable strategy is to administer boluses of 500 mL (based on clinical status) with continuous reassessment of patient response.

Blood transfusion is an independent predictor of mortality in blunt trauma [57]. Although selection bias certainly accounts for some of this increased mortality, the immunomodulatory effects of PRBC may play a role in subsequent multiorgan failure, sepsis, and death [58]. Despite these recent studies, hemorrhage shock is undoubtedly associated with elevated mortality. Early blood transfusion in the unstable elderly trauma patient should be strongly considered.

Age affects traditional measures of response to resuscitation. The physician must use a combination of clinical and laboratory parameters to judge the effectiveness of the resuscitation. Foley catheters should be placed in all major trauma patients who lack contraindication. Urine output, although not a reliable marker of fluid status in the elderly, can still provide clinically relevant information and should be monitored in the emergency department. Initial arterial blood gas and venous lactate are recommended. Base deficit (BD) and serum lactate provide important information in the triage and resuscitation of the elderly trauma patient. Lactate and BD levels correlate with systemic hypoperfusion and shock. Admission levels of these markers correlate with ICU length of stay (LOS), hospital LOS, ISS, and mortality. In the elderly patient who has clear signs of shock, normalizing lactate and BD levels are useful markers of adequate resuscitation. The concept of "lac time" or clearance of BD has been shown to correlate with successful resuscitation and mortality [59,60]. Any trauma patient who remains in the emergency department for more than 45 minutes should have serial lactate levels drawn. Although an abnormal base deficit clearly suggests significant pathology, a normal BD does not rule out disease. In a study by Davis and colleagues [61] elderly patients who had a normal BD had mortality rates of 24%. The use of lactate and BD in the emergency department is to quickly identify OH and guide early aggressive resuscitation. In an apparently hemodynamically stable patient, admission BD of −6 or less or lactate of 2.4 mmol or greater suggests occult hypoperfusion and should prompt further clinical investigation and aggressive resuscitation.

Invasive monitoring with pulmonary artery catheters (PAC) seems superior to central venous catheters and central venous pressure measurement for guiding the resuscitation of elderly trauma patients. In a study of 67 elderly patients who had hip fractures, Schultz and colleagues [62] showed that use of a PAC to guide resuscitation decreased mortality from 29% to 2.9% [63]. Scalea and colleagues [64], in a study of pedestrian motor vehicle trauma, found that elderly patients who had systolic blood pressure 130 to 150 mm Hg had high rates of occult hypoperfusion. In these patients, PAC-guided resuscitation to cardiac index of at least 4 $L/min/m^2$ and an oxygen consumption of 170 $mL/min/m^2$ improved mortality. These resuscitation endpoints are used in several trauma centers around the country.

Recently, Brown and colleagues [65] demonstrated in a retrospective analysis that noninvasive monitoring with bioelectrical impedance devices was comparable to PAC thermodilution techniques for estimating cardiac index in the geriatric trauma patient. Future prospective trails may show this promising technique to be easier, safer, and as effective as the PAC.

Summary

1. Any elderly patient who has physiologic compromise, significant injury (TS < 14), high risk mechanism, or preexisting medical condition with altered cardiovascular function, should be monitored with pulmonary artery catheter.
2. Reasonable resuscitation endpoints are cardiac index of 4 L/min/m^2 or O_2 consumption index of 170 mL/min/m^2.
3. BD and lactate clearance provide guidance as to the status of hemodynamic resuscitation.
4. Aggressive intravenous fluid, blood, and maximizing cardiac index with inotropes improves survival.

Solid organ injuries

The management of blunt abdominal trauma and solid organ injury in elderly patients continues to evolve. In the emergency department, fluid resuscitation, aggressive hemodynamic monitoring, and early diagnosis of injuries are fundamental. Historically, surgeons have considered advanced age as a prohibitive risk for consideration of NOM of blunt solid organ injury [66]. Early studies suggested a 60% to 90% failure rate for NOM of blunt splenic trauma in patients greater than 55 years old [57]. More recent studies indicate that in properly selected elderly blunt trauma patients, NOM has success rates of 62% to 85% [67–69]. Some 90% of hepatic trauma is managed nonoperatively with failure rate ranging from 5% to 15% across all age groups [70,71]. The Eastern Association for the Surgery of Trauma reported that hemodynamic stability, grade of injury, and the GCS score predicted the success of NOM of blunt splenic injuries in adults. Other studies show that successful NOM rates are equivalent between elderly and younger cohort. Accordingly, patients of advanced age who have solid organ injury can be managed nonoperatively.

Complications of NOM occur in approximately 3% to 11% of adult patients. Operative reports suggest a 1% to 3% rate of missed bowel injuries, delayed hemorrhage, delayed infections, bilomas, and hemobilia [72]. Higher ISS, increased hemoperitoneum, continued contrast blush or extravasation, and hemodynamic instability predict the need for surgery. Most elderly patients who fail NOM do so within the first 48 to 72 hours after injury [73]. Elderly patients who fail NOM seem to have worse clinical outcomes than younger patients [39]. Consideration of operative intervention should occur with unstable hematocrit, increasing abdominal pain, persistent unexplained tachycardia, or hemodynamic decompensation or instability. Markers of occult hypoperfusion, such as lactate and base excess, may play an important role in identifying the elderly trauma patient who has a solid organ injury and impending hemodynamic collapse.

Angiographic embolization (AE) is playing an increasingly important role in the NOM of solid organ injuries in the elderly. No reports specifically address the use of angiographic embolization in the elderly population. Several conclusions may be extrapolated from the adult trauma literature, however. Two techniques exist for splenic embolization: proximal (ie, main splenic artery) and distal (ie, selective embolization). In a series of 150 adult patients, Sclafani and colleagues [74] demonstrated a 98.5% salvage rate with splenic AE on hemodynamically stable trauma patients. Other studies report failure rates closer to 10% to 13.5% with a 20% complication rate (eg, recurrent hemorrhage, missed injuries, or infection) [75]. Success and complication rates are likely somewhat institution dependent [76]. Angiography is a reasonable option for the elderly trauma patient who has solid organ injury and demonstrable blush or extravasation on CT regardless of hemodynamic stability [72]. The physician should ensure that the hemodynamic collapse is not attributable to other injuries before transferring the patient to the angiography suite.

Pelvic fractures

Pelvic fractures in the elderly are a distinct clinical entity. In general, pelvic fractures require a significant transfer of kinetic energy and are associated with a high incidence of polytrauma. In the elderly, however, low-energy trauma (eg, fall from standing) is the most common mechanism of injury, followed closely by motor vehicle crash (MVC). Despite this fact, polytrauma is as common as with younger patients and the incidence of associated thoracic trauma in the elderly is significantly increased [77].

Age is an independent predictor of mortality in trauma patients who have pelvic fractures. Overall mortality from either acute or delayed complications (hemorrhage, multiorgan failure, sepsis) is 9% to 30% The disparity is most pronounced in the moderate severity patients (ie, ISS of 16–25) in whom elder mortality is 21% compared with 6% in the younger cohort [78]. The elderly do particularly poorly with open pelvic fractures; one study demonstrated mortality up to 81% [78].

Fracture patterns are similar between elderly and younger trauma patients. The pubic rami is most commonly fractured (56%), followed by the acetabulum (19%) and ischium (11%). More than 50% of patients suffer multiple fractures. The mechanisms and clinical sequelae differ significantly in the elderly, however. The elderly are less likely to have "severe" pelvic fractures as defined by the American Orthopedic Association, yet suffer far higher mortality. Lateral compression (LC) fractures are nearly five times more common that anteroposterior (AP) fractures [78]. In contrast to younger patients in whom LC fractures are associated with lower transfusion rates and increased survival, these fractures in the elderly trauma patient result in significantly higher rates of hemorrhage, transfusion, angiographic embolization, and admission to the ICU.

Emergent treatment of the elderly patient who has a pelvic fracture focuses on control of hemorrhage, stabilization of the fracture, pain control, and resuscitation. The elderly have higher rates of hemorrhage despite lower fracture severity perhaps secondary to atherosclerotic changes that retard vasospasm and "loose" periosteum that limits tamponade. Blackmore and colleagues [79] proposed a clinical decision rule for predicting major hemorrhage after pelvic fractures. In this study, heart rate greater than 130 bpm, hematocrit less than 30, obturator ring fractures greater than 1 cm, and greater than 1-cm disruption of the pubic symphysis diastasis were associated with major pelvic fracture–related hemorrhage. The NPV of this decision rule is limited in the elderly given higher rates of lateral compression fractures and blunted ability to mount a tachycardic response to hypovolemia.

All elderly trauma patients who have suspected pelvic fractures should be typed and crossed for four to six units of blood. Attaining hemostasis is a priority in the trauma bay. Disruption of the posterior pelvic ring is associated with increased hemorrhage and subsequent hypotension. External fixation is useful for reducing pelvic volume in patients who have AP-type pelvic fractures. External fixation is not useful in the patient who has an LC fracture, the major clinically significant pelvic fracture seen in elderly blunt trauma patient.

Retroperitoneal hemorrhage is common after geriatric pelvic trauma and is not amenable to surgical repair; thus AE is an important treatment modality for elderly patients who have pelvic fractures. Timing of embolization is debated in the literature. Some studies suggest AE after a transfusion threshold of six units; these studies have reported mortality rates of approximately 30% [80]. Alternatively, it can be offered early in the clinical course based on fracture patterns, pelvic hematoma on CT, tachycardia, and declining hematocrit. Liberal arterial embolization seems to increase the effectiveness of hemostasis but with the expected increase in rates of unnecessary procedures. Age greater than 55 years is a powerful indication for angiographic embolization in the patient who has a pelvic fracture given the eightfold increase in risk for major hemorrhage [81]. Age greater than 60 is associated with an even higher rate of retroperitoneal bleed and need for embolization (PPV 94%). In these patients, embolization decreases mortality despite admission hemodynamic status.

Given the low rates of complication from AE (3%–4% commonly reported) and the high mortality from ongoing hemorrhage, early AE should be considered in elderly patients who have pelvic fracture, any suggestion of hemodynamic compromise, evidence of pelvic hematoma on CT, or transfusion requirements of greater than four units. Most pelvic fractures in the elderly require admission to the hospital. Any signs of continued hemorrhage or instability warrant admission to the ICU.

Traumatic brain injury

TBI and intracranial hemorrhage (ICH) are common injuries in the elderly trauma patient, accounting for approximately 80,000 emergency department visits annually [82]. Seventy five percent of these patients require admission with an age-adjusted hospitalization rate of 156 per 100,000 population, twice that of trauma patients less than 65 years of age [83,84]. Age is an independent predictor of mortality and disability in patients who have moderate to severe head trauma [85]. Compared with younger patients, even with equivalent or lower trauma triage scores (ISS, RTS, and GCS), the elderly have longer hospital stays, increased ICU usage, lower rates of functional recovery, and significantly higher mortality [86]. Patients older than 65 years have mortality rates two to five times those of younger patients with matched GCS and intracranial pathology [87]. Overall mortality rates in elderly patients who have TBI with ICH range from 30% to 85% [84,88].

Multiple factors contribute to the increased morbidity and mortality observed in elderly patients who have TBI. Brain weight decreases 10% between ages 30 to 70 years [89]. This age-related cerebral atrophy increases the distance traversed by bridging veins resulting in a loss of venous tortuosity. The veins remain firmly adhered to brain and dura and are more susceptible to traumatic tears with subsequent subdural hematomas. Cerebral atrophy also increases intracranial free space, potentially masking ongoing bleeds, resulting in subtle presentations and delaying the diagnosis. In addition to these anatomic changes, elderly trauma patients have significantly higher rates of comorbidities (eg, COPD, CAD, hypothyroidism, and so forth) that can exacerbate the dangerous triad of hypotension, hypoxia, and hypocoagulability. Dementia and cognitive deterioration are frequently encountered in the elderly trauma patient. In addition to being an independent risk factor for falls and TBI, cognitive impairment may complicate the emergency assessment of the elderly trauma patient and delay diagnosis and treatment. Finally, the use of medications, such as Coumadin, aspirin, and clopidogrel bisulfate (Plavix), dramatically increases the morbidity associated with elderly TBI [84,90,91].

Currently, physicians prescribe warfarin to more than 1 million Americans and in elderly trauma patients who have TBI, nearly 9% are on Coumadin [92]. Coumadin, aspirin, Plavix and Lovenox are critical medications responsible for the improved survivability from strokes, acute myocardial infarction, thromboembolic events, and atrial fibrillation. The incidence of adverse thromboembolic events in subtherapeutically anticoagulated patients who have mechanical heart valves or atrial fibrillation is 2% to 12%

per year depending on age, coexisting risk factors, and prior ischemic events [93]. The use of Coumadin decreases these adverse events by 50% to 75% [94]. These agents also dramatically increase the morbidity and mortality from traumatic intracerebral hemorrhage, however [87]. Recent reports indicate that spontaneous ICH rates in anticoagulated patients range from 0.3% to 5.4% per year [95]. In anticoagulated patients who have blunt head trauma and minimal or no symptoms, the rate of significant intracranial hemorrhage approaches 7% to 14% [96].

The elderly patient who has TBI and is on anticoagulation, specifically Coumadin, poses a significant diagnostic and management challenge. Most studies show that Coumadin is an independent predictor of mortality in traumatic brain injuries resulting in a 3- to 10-fold increase in mortality from TBI in the elderly [91,97–99]. Several studies also indicate that the elderly are significantly more likely to present with supratherapeutic international normalized ratio (INR). Increased rates of hepatic disease, poor nutrition, and variable medical compliance likely contribute to this dangerous trend.

The physician should order an INR and cranial CT on all elderly trauma patients who have suspected TBI. Clinical demise, evidence of intracranial hemorrhage, or supratherapeutic INR are all indications for pharmacologic reversal of anticoagulation [97,100,101]. In these situations, the risk for immediate mortality far outweighs the risk for adverse embolic events from the preexisting condition. Several studies have demonstrated that temporary discontinuation of warfarin, aspirin, or Plavix in the setting of ICH does not increase the risk for thrombotic or ischemic events [92,102–104].

Multiple reversal strategies exist. Volume of blood from the ruptured vessel and hematoma expansion are the most important determinants of morbidity and mortality in intracerebral hemorrhage [105]. All efforts should be made to limit continued bleeding. Ivascu and colleagues [97] found that implementation of a reversal protocol using early cranial CT from triage, immediate transfusion of two units of unmatched fresh frozen plasma (FFP) followed by two units of matched FFP decreased the time to reversal from 4.3 to 1.9 hours. In this study, progression of ICH dropped from 40% to 11% and subsequent mortality improved from 50% to 10%. The volume of FFP required to reverse fully the anticoagulation may range from 2 to 4 L, creating potential limitations in the elderly trauma patient who has concomitant fluid overload [101]. In these instances, alternative protocols may be useful.

Cryoprecipitate, vitamin K, prothrombin complex concentrates (PCC), and recombinant activated factor VIIa (rfVIIa) are also viable options in the treatment of anticoagulated patients who have TBI. In multiple studies of nontraumatic intracranial hemorrhage, immediate administration of PCC was associated with more rapid reversal of INR and subsequent decreased hematoma growth than vitamin K and FFP [106,107]. Typical PCC dosages are 25 to 50 IU/kg based on body weight, degree of anticoagulation, and desired level of correction [108]. Several studies of atraumatic cerebral hemorrhage suggest that administration of rFVIIa within 4 hours after the onset of insult limits the growth of the hematoma, reduces mortality, and improves functional outcomes at 90 days [109]. Future studies will delineate the role of rFVIIa in the management of acute traumatic intracerebral hemorrhage in the anticoagulated patient. Reasonable strategies include vitamin K (10 mg IV or 5 to 10 mg subcutaneously) coupled with a faster acting reversal agent, such as FFP, PCC, or rFVIIa.

Antiplatelet agents, such as aspirin and clopidogrel, are also becoming increasingly common in the elderly population. As with Coumadin, aspirin and clopidogrel have untoward effects on the elderly trauma patient who has TBI. The cardiology literature suggests that clopidogrel is a more effective antiplatelet agent than aspirin; many patients are on dual therapy. In small studies of TBI in elderly patients on single-medication regimens, aspirin and clopidogrel seem to have similar mortality. There also seems to be no significant difference in mortality for patients on combination antiplatelet therapy versus single-agent regimens [90]. Reversal strategies for these patients are based on bench science, in vitro studies, and theoretic physiologic principles. Platelet transfusions may offset some of the bleeding consequences of aspirin and Plavix. Although no data exist in the trauma literature, some cardiothoracic surgery literature suggests that Desmopressin at doses of 15 μg/L may also slow hemorrhage in patients taking aspirin [110]. One recent study successfully used recombinant factor VIIa to reverse the inhibitory effects of aspirin or aspirin and clopidogrel on in vitro thrombin formation [111].

Any elderly trauma patient who has TBI on anticoagulation or with documented intracranial pathology on head CT should be admitted to the neurosurgical service. These patients are particularly susceptible to rapid clinical deterioration and aggressive hemodynamic monitoring is advisable. A recent study by Cohen and colleagues [112] of anticoagulated patients who had head trauma demonstrated two disturbing points. First, most of their patients were supratherapeutic with INR greater than 5.0 in 50% of patients who had severe head injuries and greater than 3.0 in 47% of patients who had minor head injuries. Second, of 77 patients who had GCS 13 to 15 who were either initially discharged or admitted for observation, 56 deteriorated clinically with a mortality rate for these patients who had minor head injury of greater than 80%. Although this mortality is likely multifactorial and related to the high rate of supratherapeutic anticoagulation, the point is clear: anticoagulated elderly patients who have traumatic brain injuries are extremely high risk [88]. Elderly patients who have isolated head trauma, normal cranial CT, and elevated INR do not require pharmaceutical reversal but should be observed in the hospital for 12 to 24 hours [113]. Elderly patients who have normal head CT, normal INR, and no other associated injuries may be discharged if they have a responsible care provider and have reliable follow up.

Rib fractures

Blunt thoracic trauma is responsible for 25% of all trauma deaths in the United States. Two thirds of these patients have rib fractures and up to 35% are affected by pulmonary complications [31]. The elderly are more susceptible to rib fracture from relatively minor trauma. In the study by Bergeron and colleagues [114], falls from standing accounted for greater than 50% of elderly patients who had blunt trauma admitted with rib fractures followed closely by MVCs. In MVCs, the elderly are more susceptible to rib fractures from seat belts in low-speed and medium-speed accidents [115].

Despite lower indices of injury severity, elderly patients have twice the mortality and thoracic morbidity of younger patients (22% versus 10%) [114,116]. In Bulger and colleagues' [21] study of 277 patients older than 65 years of age who had rib fractures, mortality increased 19% and the risk for pneumonia increased 27% for each rib fracture. Further, the presence of rib fractures in thoracic trauma patients correlated with a 1.7-time increase in hepatic injury and 1.4-time increase in splenic injury. This finding is of added significance in the elderly trauma patient in whom baseline hepatic dysfunction significantly increases trauma-related mortality.

The elderly patient who has rib fractures is more likely to present with hypotension and has a significantly higher risk for sternal fracture [21]. Aggressive pain management and hemodynamic monitoring are particularly important. Control of fracture-associated pain decreases splinting, reduces atelectasis, and may limit subsequent pulmonary sequelae. Multiple strategies exist for pain management in the elderly. IV narcotic analgesia and patient-controlled analgesia are often effective but may be limited by central nervous system effects and further depression of respiratory drive [117]. The use of epidural analgesia with agents such as bupivacaine and fentanyl reportedly provides superior pain control without the sedating effect of parenteral opioids [114,118].

Scant prospective data exist concerning the use of epidurals in elderly trauma patients who have rib fractures and retrospective mortality data are mixed. Some studies suggest that the use of epidural analgesia correlates with increased length of stay and pulmonary complications [117]. This finding may represent selection bias toward using this procedure with more severely injured patients. Other reports indicate that epidural analgesia is associated with a decrease in the rate of nosocomial pneumonia and a shorter duration of mechanical ventilation after rib fractures [21]. In one large study, epidural use demonstrated a significant reduction in mortality from 16% to 10% at 48 hours postinjury [119]. The use of epidural analgesia may be limited in the elderly trauma population because of numerous exclusion criteria (eg, thoracic vertebral body fractures, spinal cord injuries, ongoing coagulopathy, bacteremia, and severe head injury) [21]. In appropriate patients, however, it seems to decrease mortality and should be considered early in the course of treatment of multiple rib fractures in selected elderly trauma patients.

Age and ISS predict mortality in patients who have rib fractures and multisystem injury [120]. Elderly trauma patients who have greater than two isolated rib fractures should be admitted to the hospital for observation. With greater than six rib fractures, morbidity and mortality are high; the patient should be admitted to an intensive care unit [117]. Aggressive pulmonary toilet, airway monitoring, and pain control should be initiated early in the emergency department.

Summary

Elderly trauma patients present unique challenges and face more significant obstacles to recovery than younger patients. Despite overall higher mortality, longer LOS, increased resource use, and higher rates of discharge to rehabilitation, most elderly trauma patients return to independent or preinjury functional status. Critical to improving these outcomes is an understanding that although similar trauma principles apply to the elderly, they require more aggressive evaluation and resuscitation.

References

[1] U.S. Bureau of the Census. Jennifer Cheeseman day, population projections of the United States, by age, sex, race, and Hispanic origin: 1993 to 2050, current population reports, P25–1104. Washington, DC: U.S. Government Printing Office; 1993.

[2] Broos P. Multiple trauma in elderly patients: factors influencing outcome. Injury 1993;24(6):365–8.

[3] Champion HR, Copes SW, Buyer D, et al. Major trauma in geriatric patients. Am J Public Health 1989;79(9):1278–82.

[4] Osler T, Hales K, Baack B, et al. Trauma in the elderly. Am J Surg 1988;156(6):537–43.

[5] Jacobs DG, Plaisier BR, Barie PS, et al. Practice management guidelines for geriatric trauma: the EAST practice management guidelines work group. J Trauma 2003;54:391–416.

[6] Ma MH, MacKenzie EJ, Alcorta R, et al. Compliance with prehospital triage protocols for major trauma patients. J Trauma 1999;46:168–75.

[7] Phillips S, Rond PC, 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.

[8] Mandavia D, Newton K. Geriatric trauma. Emerg Clin North Am 1998;16:257–74.

[9] Sterling DA, O'Connor JA, Bonadies J. Geriatric falls: injury severity is high and disproportionate to mechanism. J Trauma 2001;50(1):116–9.

[10] Knudson MM, Lieberman J, Morris J, et al. Mortality factors in geriatric blunt trauma patients. Arch Surg 1994;129(4):448–53.

[11] Horst HM, Obeid FN, Sorensen VJ, et al. Factors influencing survival of elderly trauma patients. Crit Care Med 1986;14(8):681–4.

[12] Tornetta P, Mostafavi M, Riina J, et al. Morbidity and mortality in elderly trauma patients. J Trauma 1999;46(4):702–6.

[13] Demaria EJ, Kenney PR, Merriam MA, et al. Survival after trauma in geriatric patients. Ann Surg 1987;206(6):738–43.

[14] American College of Surgeons. Advanced trauma life support for doctors. American College of Surgeons Committee on Trauma. 7th edition. Chicago (IL): American College of Surgeons; 2004.

[15] Demetriades D, Sava J, Alo K, et al. Old age as a criterion for trauma team activation. J Trauma 2001;51:754–6.
[16] Demaria EJ, Kenney PR, Merriam MA, et al. Aggressive trauma care benefits the elderly. J Trauma 1987;27(11):1200–6.
[17] Trauma. 3rd edition. 1996. In: Felician DV, Moore EE, Mattox KL. editors. McGraw-Hill; 2003.
[18] Aziz L, Jahangir SM, Choudhury SN, et al. The effect of priming with vecuronium and rocuronium on young and elderly patients. Anesth Analg 1997;85(3):663–6.
[19] Narang AT, Sikka R. Resuscitation of the elderly. Emerg Med Clin North Am 2006;24(2): 261–72, v.
[20] Allolio B, Dorr H, Stuttmann R, et al. Effect of a single bolus of etomidate upon eight major corticosteroid hormones and plasma ACTH. Clin Endocrinol (Oxf) 1985;22(3): 281–6.
[21] Bulger EM, Arneson MA, Mock CN, et al. Rib fractures in the elderly. J Trauma 2000; 48(6):1040–7.
[22] Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. Ann Surg 1998;228(4): 557–67.
[23] McGahan JP, Richards J, Fogata ML. Emergency ultrasound in trauma patients. Radiol Clin North Am 2004;42(2):417–25, [review].
[24] Richards JR, McGahan JP, Pali MJ, et al. Sonographic detection of blunt hepatic trauma: hemoperitoneum and parenchymal patterns of injury. J Trauma 1999;47(6):1092–7.
[25] Lee BC, Ormsby EL, McGahan JP, et al. The utility of sonography for the triage of blunt abdominal trauma patients to exploratory laparotomy. AJR Am J Roentgenol 2007;188(2):415–21.
[26] Blackbourne LH, Soffer D, McKenney M, et al. Secondary ultrasound examination increases the sensitivity of the FAST exam in blunt trauma. J Trauma 2004;57(5):934–8.
[27] Baumgarten M, Margolis DJ, Localio AR, et al. Pressure ulcers among elderly patients early in the hospital stay. J Gerontol A Biol Sci Med Sci 2006;61(7):749–54.
[28] Morris JA, MacKenzie EJ, Edelstein SL. The effect of preexisting conditions on mortality in trauma patients. JAMA 1990;263(14):1942–6.
[29] Rozzelle CJ, Wofford JL, Branch CL. Predictors of hospital mortality in older patients with subdural hematoma. J Am Geriatr Soc 1995;43:240–4.
[30] Reuter F. Traumatic intracranial hemorrhages in elderly people. Advances in Neurosurgery 1989;17:43–8.
[31] Ziegler DW, Agarwal NN. The morbidity and mortality of rib fractures. J Trauma 1994;37: 975–9.
[32] Palvanen M, Kannus P, Niemi S, et al. Hospital-treated minimal-trauma rib fractures in elderly Finns: long-term trends and projections for the future. Osteoperosis International 2004;15(8):649–53.
[33] Obaid AK, Barleben A, Porral D, et al. Utility of plain film pelvic radiographs in blunt trauma patients in the emergency department. Am Surg 2006;72(10):951–4.
[34] Gross EA, Niedens BA. Validation of a decision instrument to limit pelvic radiography in blunt trauma. J Emerg Med 2005;28(3):263–6.
[35] Pehle B, Nast-Kolb D, Oberbeck R, et al. [Significance of physical examination and radiography of the pelvis during treatment in the shock emergency room]. Unfallchirurg 2003;106(8):642–8.
[36] Gonazalez RP, Fried PQ, Bukahlo M. The utility of clinical examination in screening for pelvic fractures in blunt trauma. J Am Coll Surg 2002;194(2):121–5.
[37] Stuhlfaut JW, Soto JA, Lucey BC, et al. Blunt abdominal trauma: performance of CT without oral contrast material. Radiology 2004;233(3):689–94, [E-pub 2004 Oct 29].
[38] Tsugawa K, Koyanagi N, Hashizume M, et al. New insight for management of blunt splenic trauma: significant differences between young and elderly. Hepatogastroenterology 2002; 49(46):1144–9.

[39] Harbrecht BG, Peitzman AB, Rivera L, et al. Contribution of age and gender to outcome of blunt splenic injury in adults: multicenter study of the Eastern Association for the Surgery of Trauma. J Trauma 2001;51(5):887–95.
[40] Willmann JK, Roos JE, Platz A, et al. Multidetector CT: detection of active hemorrhage in patients with blunt abdominal trauma. AJR Am J Roentgenol 2002;179(2):437–44.
[41] Anderson SW, Varghese JC, Lucey BC, et al. Blunt splenic trauma: delayed-phase CT for differentiation of active hemorrhage from contained vascular injury in patients. Radiology 2007 [E-pub ahead of print].
[42] Weisbord SD, Palevsky PM. Radiocontrast-induced acute renal failure. J Intensive Care Med 2005;20:63–75.
[43] Barrett BJ, Parfrey PS. Preventing nephropathy induced by contrast medium. N Engl J Med 2006;354:379–86.
[44] Toprak O, Cirit M. Risk factors and therapy strategies for contrast-induced nephropathy. Ren Fail 2006;28(5):365–81, [review].
[45] Papaioannou A, Watts NB, Kendler DL, et al. Diagnosis and management of vertebral fractures in elderly adults. Am J Med 2002;113(3):220–8, [review].
[46] Berry GE, Adams S, Harris MB, et al. Are plain radiographs of the spine necessary during evaluation after blunt trauma? Accuracy of screening torso computed tomography in thoracic/lumbar spine fracture diagnosis. J Trauma 2005;59(6):1410–3, [discussion: 1413].
[47] Brown CV, Antevil JL, Sise MJ, et al. Spiral computed tomography for the diagnosis of cervical, thoracic, and lumbar spine fractures: its time has come. J Trauma 2005;58(5):890–5, [discussion: 895–6].
[48] Mosenthal AC, Livingston DH, Elcavage J, et al. Falls: epidemiology and strategies for prevention. J Trauma 1995;38:753–6.
[49] Ibanez J, Arikan F, Pedraza S, et al. Reliability of clinical guidelines in the detection of patients at risk following mild head injury: results of a prospective study. J Neurosurg 2004;100(5):825–34.
[50] Mack LR, Chan SB, Silva JC, et al. The use of head computed tomography in elderly patients sustaining minor head trauma. J Emerg Med 2003;24(2):157–62.
[51] Clement CM, Stiell IG, Schull MJ, et al. CCC Study Group. Clinical features of head injury patients presenting with a Glasgow Coma Scale score of 15 and who require neurosurgical intervention. Ann Emerg Med 2006;48(3):245–51.
[52] Haydel MJ, Preston CA, Mills TJ, et al. Indications for computed tomography in patients with minor head injury. N Engl J Med 2000;343(2):100–5.
[53] Stein SC, Burnett MG, Glick HA. Indications for CT scanning in mild traumatic brain injury: a cost-effective study. J Trauma 2006;61:558–66.
[54] Gittleman AM, Ortiz AO, Keating DP, et al. Indications for CT in patients receiving anticoagulation after head trauma. Am J Neuroradiol 2005;26:603–6.
[55] van Aalst JA, Morris JA Jr, Yates HK, et al. Severely injured geriatric patients return to independent living: a study of factors influencing function and independence. J Trauma 1991;31(8):1096–101; [discussion 110–12].
[56] Roberts I, Alderson P, Bunn F, et al. Colloids versus crystalloids for fluid resuscitation in critically ill patients. Cochrane Database Syst Rev 2004;18(4):CD000567, [review].
[57] Charles A, Shaikh AA, Walters M, et al. Blood transfusion is an independent predictor of mortality after blunt trauma. Am Surg 2007;73(1):1–5.
[58] Claridge JA, Sawyer RG, Schulman AM, et al. Blood transfusions correlate with infections in trauma patients in a dose-dependent manner. Am Surg 2002;68:566–72.
[59] McNelis J, Marini CP, Jurkiewicz A, et al. Prolonged lactate clearance is associated with increased mortality in the surgical intensive care unit. Am J Surg 2001;182(5):481–5.
[60] Husain FA, Martin MJ, Mullenix PS, et al. Serum lactate and base deficit as predictors of mortality and morbidity. Am J Surg 2003;185(5):485–91.
[61] Davis JW, Kaups KL. Base deficit in the elderly: a marker of severe injury and death. J Trauma 1998;45:873–7.

[62] Schultz RJ, Whitfield GF, LaMurra JJ, et al. The role of physiologic monitoring in patients with fractures of the hip. J Trauma 1985;45:309–16.
[63] Victorino GP, Chong TJ, Pal JD. Trauma in the elderly patient. Arch Surg 2003;138: 1093–8.
[64] Scalea TM, Simon HM, Duncan AO, et al. Geriatric blunt multiple trauma: improved survival with early invasive monitoring. J Trauma 1990;30(2):129–34, [discussion 134–6].
[65] 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.
[66] Godley CD, Warren RL, Sheridan RL, et al. Nonoperative management of blunt splenic injury in adults: age over 55 years as a powerful indicator for failure. J Am Coll Surg 1996;183(2):133–9.
[67] Barone JE, Burns G, Svehlak SA, et al. Management of blunt splenic trauma in patients older than 55 years. Southern Connecticut Regional Trauma Quality Assurance Committee. J Trauma 1999;46(1):87–90.
[68] Falimirski ME, Provost D. Nonsurgical management of solid abdominal organ injury in patients over 55 years of age. Am Surg 2000;66(7):631–5.
[69] Albrecht RM, Schermer CR, Morris A. Nonoperative management of blunt splenic injuries: factors influencing success in age >55 years. Am Surg 2002;68(3):227–30, [discussion: 230–1].
[70] Hurtuk M, Reed RL 2nd, Esposito TJ, et al. Trauma surgeons practice what they preach: the NTDB story on solid organ injury management. J Trauma 2006;61(2):243–54, [discussion: 254–5].
[71] Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg 2005;200(5):648–69, [review].
[72] Schurr MJ, Fabian TC, Gavant M, et al. Management of blunt splenic trauma: computed tomographic contrast blush predicts failure of nonoperative management. J Trauma 1995; 39(3):507–12, [discussion: 512–3].
[73] Cocanour CS, Moore FA, Ware DN, et al. Delayed complications of nonoperative management of blunt adult splenic trauma. Arch Surg 1998;133:619–24.
[74] Sclafani SJ, Shaftan GW, Scalea TM, et al. Nonoperative salvage of computed tomography-diagnosed splenic injuries: utilization of angiography for triage and embolization for hemostasis. J Trauma 1995;39(5):818–25, [discussion: 826–7].
[75] Haan JM, Bochicchio GV, Kramer N, et al. Nonoperative management of blunt splenic injury: a 5-year experience. J Trauma 2005;58(3):492–8.
[76] Dent D, Alsabrook G, Erickson BA, et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. J Trauma 2004;56(5): 1063–7.
[77] O'Brien DP, Luchette FA, Pereira SJ, et al. Pelvic fracture in the elderly is associated with increased mortality. Surgery 2002;132:710–4.
[78] Martin RE, Teberian G. Multiple trauma and the elderly patient. Emerg Med Clin North Am 1990;8(2):411–20.
[79] Blackmore CC, Cummings P, Jurkovich GJ, et al. Predicting major hemorrhage in patients with pelvic fracture. J Trauma 2006;61(2):346–52.
[80] Kimbrell BJ, Velmahos GC, Chan LS, et al. Angiographic embolization for pelvic fractures in older patients. Arch Surg 2004;139(7):728–32, [discussion: 732–3].
[81] Velmahos GC, Toutouzas KG, Vassiliu P, et al. A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries. J Trauma 2002;53(2): 303–8, [discussion: 308].
[82] Thompson HJ, McCormick WC, Kagan SH. Traumatic brain injury in older adults: epidemiology, outcomes, and future implications. J Am Geriatr Soc 2006;54:1590–5.
[83] Coronado VG, Thomas KE, Sattin RW, et al. The CDC traumatic brain injury surveillance system: characteristics of persons aged 65 years and older hospitalized with a TBI. J Head Trauma Rehabil 2005;20:215–28.

[84] Lavoie A, Ratte S, Clas D, et al. Preinjury warfarin use among elderly patients with closed head injuries in a trauma center. J Trauma 2004;56:802–7.
[85] Masson F, Thicoipe M, Mokni T, et al. Aquitaine group for severe brain injury study. Epidemiology of traumatic comas: a prospective population-based study. Brain Inj 2003; 17(4):279–93.
[86] Susman M, DiRusso SM, Sullivan T, et al. Traumatic brain injury in the elderly: increased mortality and worse functional outcome at discharge despite lower injury severity. J Trauma 2002;53:219–24.
[87] Cohen DB, Rinker C, Wilberger JE. Traumatic brain injury in anticoagulated patients. J Trauma 2006;60:553–7.
[88] Amacher AL, Bybee DE. Toleration of head injury by the elderly. Neurosurgery 1987;20:954–8.
[89] Ellis GL. Subdural hematoma in the elderly. Emerg Med Clin North Am 1990;8(2):281–94.
[90] Ohm C, Mina A, Howells G, et al. Effects of antiplatelet agents on outcomes for elderly patients with traumatic intracranial hemorrhage. J Trauma 2005;58:518–22.
[91] Franko J, Kish KJ, O'Connell BG, et al. Advanced age and preinjury warfarin anticoagulation increase the risk of mortality after head trauma. J Trauma 2006;61:107–10.
[92] Kirsch MJ, Vrabec GA, Marley RA, et al. Preinjury warfarin and geriatric orthopedic trauma patients: a case-matched study. J Trauma 2004;57:1230–3.
[93] Cannegieter SC, Rosendaal FR, Wintzen AR, et al. Optimal oral anticoagulant therapy in patients with mechanical heart valves. N Engl J Med 1995;333(1):11–7.
[94] Wijdicks EF, Schievink WI, Brown RD, et al. The dilaemma of discontinuation of anticoagulation therapy for patients with intracranial hemorrhage and mechanical heart valves. Neurosurgery 1998;42(4):769–73.
[95] Shireman TI, Mahnken JD, Howard PA, et al. Development of a contemporary bleeding risk model for elderly warfarin recipients. Chest 2006;130:1390–6.
[96] Li J, Brown J, Levine M. Mild head injury, anticoagulants, and risk of intracranial injury. Lancet 2001;357:771–2.
[97] Ivascu FA, Janczyk RI, Junn FS, et al. Treatment of trauma patients with intracranial hemorrhage on preinjury warfarin. J Trauma 2006;61:318–21.
[98] Ivascu FA, Howells GA, Junn FS, et al. Rapid warfarin reversal in anticoagulated patients with traumatic intracranial hemorrhage reduces hemorrhage progression and mortality. J Trauma 2005;59:1131–9.
[99] Karni A, Holtzman R, Bass T, et al. Traumatic head injury in the anticoagulated elderly patient: a lethal combination. Am Surg 2001;67(11):1098–100.
[100] Rathlev N, Medzon R, Lowery D, et al. Intracranial pathology in the elderly with minor head injury. Acad Emerg Med 2006;13(3):302–7.
[101] Aguilar MI, Hart RG, Kase CS, et al. Treatment of warfarin-associated intracerebral hemorrhage: literature review and expert opinion. Mayo Clin Proc 2007;82(1):82–92, [review. erratum in: Mayo Clin Proc. Mar 2007;82(3):387].
[102] Phan TG, Koh M, Wijdicks EF. Safety of discontinuation of anticoagulation in patients with intracerebral hemorrhage at high thromboembolic risk. Arch Neurol 2000; 57:1710–3.
[103] Babikian VL, Kase CS, Pressin MS, et al. Resumption of anticoagulation after intracranial bleeding in patients with prosthetic heart valves. Stroke 1988;19:407–8.
[104] Kawamata T, Takeshita M, Kubo O, et al. Management of intracranial hemorrhage associate with anticoagulation therapy. Surg Neurol 1995;44:438–42.
[105] Goldstein JN, Thomas SH, Frontiero V, et al. Timing of fresh frozen plasma administration and rapid correction of coagulopathy in warfarin-related intracerebral hemorrhage. Stroke 2006;37:151–5.
[106] Cartmill M, Dolan G, Byrne JL, et al. Prothrombin complex concentrate for oral anticoagulant reversal in neurosurgical emergencies. Br J Neurosurg 2000;14(5):458–61.
[107] Huttner HB, Schellinger PD, Hartmann M, et al. Hematoma growth and outcome in treated neurocritical care patients with intracerebral hemorrhage related to oral

anticoagulant therapy: comparison of acute treatment strategies using vitamin K, fresh frozen plasma, and prothrombin complex concentrates. Stroke 2006;37(6):1465–70, [E-pub 2006 May 4].
[108] Preston FE, Laidlaw ST, Sampson B, et al. Rapid reversal of oral anticoagulation with warfarin by a prothrombin complex concentrate (Beriplex): efficacy and safety in 42 patients. Br J Haematol 2002;116:619–24.
[109] Mayer SA, Brun NC, Begtrup K, et al. Recombinant activated factor VII intracerebral hemorrhage trial investigators. Recombinant activated factor VII for acute intracerebral hemorrhage. N Engl J Med 2005;352(8):777–85.
[110] Aschkenasy MT, Rothenhaus TC. Trauma and falls in the elderly. Emerg Med Clin N Am 2006;24:413–32.
[111] Altman R, Scazziota A, DE Lourdes Hererra M, et al. Recombinant factor VIIa reverses the inhibitory effect of aspirin or aspirin plus clopidogrel on in vitro thrombin generation. J Thromb Haemost 2006;4(9):2022–7.
[112] Cohen DB, Rinker C, Wilberger JE. Traumatic brain injury in anticoagulated patients. J Trauma 2006;60(3):553–7.
[113] Itshayek E, Rosenthal G, Fraifield S, et al. Delayed posttraumatic acute subdural hematoma in elderly patients on anticoagulation. Neurosurg 2006;58(5):E851–6.
[114] Bergeron E, Lavoie A, Clas D, et al. Elderly patients with rib fractures are at greater risk of death and pneumonia. J Trauma 2003;54:478–85.
[115] Shimamura M, Ohhashi H, Yamazaki M. The effects of occupant age on patterns of rib fractures to belt-restrained drivers and front passengers in frontal crashes in Japan. Stapp Car Crash J 2003;47:349–65.
[116] Sirmali M, Turut H, Topcu S, et al. A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. Eur J Cardiothorac Surg 2003;24(1):133–8.
[117] Keininger AN, Bair HA, Bendick PJ, et al. Epidural versus intravenous pain control in elderly patients with rib fractures. Am J Surg 2005;180:327–30.
[118] Wu CL, Jani ND, Perkins FM, et al. Thoracic epidural analgesia versus intravenous patient-controlled analgesia for treatment of rib fracture pain after motor vehicle crash. J Trauma 1999;47(3):564–7.
[119] Bakhos C, O'Connor J, Kyriadides T, et al. Vital capacity as a predictor of outcome in elderly patients with rib fractures. J Trauma 2006;61:131–4.
[120] Brasel KJ, Guse CE, Layde P, et al. Rib fractures: relationship with pneumonia and mortality. Crit Care Med 2006;34(6):1642–6.