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The Value of Laboratory Testing in the Trauma Patient

Authors: **Arvind Venkat, MD, FACEP,** Resident Research Director, Department of Emergency Medicine, Allegheny General Hospital, Pittsburgh, PA; **Jennifer Yeck, MD,** Resident, Department of Emergency Medicine, Allegheny General Hospital, Pittsburgh, PA.

Peer Reviewer: **Ian Grover, MD, FACEP**, Assistant Clinical Professor of Medicine, Department of Emergency Medicine, University of California, San Diego.

Trauma patients have a wide variety of presentations and acuity, and range from healthy patients with minor injuries to patients with extensive medical histories and major trauma. The identification of all injuries is critical for appropriate management and disposition of the trauma patient. Resources that assist with identification of injuries or assessment of resuscitation are valuable aids to the ED physician and may help guide diagnostic and treatment options. Laboratory studies are a resource routinely utilized on trauma patients, but their value and benefit depend on the patient and clinical scenario.

The authors review a variety of laboratory tests routinely ordered on trauma patients and critically evaluate the value of each tool and its use in the trauma patient.

— The Editor

Introduction

The Centers for Disease Control and Prevention estimates that trauma is the source of 28.4 million emergency department (ED) visits per year.[1] Patients with traumatic injuries may be as minor as the assessment of an isolated ankle sprain to as complicated as a critically ill, multi-organ-injured geriatric patient with many co-morbid medical conditions. As such, treating physicians and nurses are typically confronted with a wide variety and acuity of trauma patients and need to efficiently evaluate patients using a variety of resources. Laboratory studies are one of the resources available to the ED physician. What is often unclear is the value that laboratory studies add to the assessment and disposition of trauma patients in the ED and other acute care settings.

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This article will review the common laboratory evaluations that may potentially aid in the assessment and treatment of trauma patients. The goal of this review is to critically evaluate the evidence that exists for ordering these tests and discuss how they can best be used to diagnose and treat traumatically injured patients. This article will also show how the existing evidence for laboratory testing in trauma patients can guide the use of these tests in particular trauma populations.

Resuscitation Assessment

One of the most common reasons for laboratory evaluation of the trauma patient is to determine the initial volume deficit and adequacy of resuscitation. Given that different patient populations with traumatic injuries can present in a varied manner as to their severity of injury, there have been multiple studies attempting to determine what, if any, laboratory test can best assess how well a patient has been resuscitated from their initial injury.

Base Deficit. For many years, both the emergency medicine literature and the trauma literature have contained studies pointing to base deficit as a marker of the need for resuscitation in trauma patients.[2,3] The base deficit is obtained either by arterial or venous blood gas with an algorithmic calculation of the deficit of bicarbonate given the measured pH and pCO_2. This value usually represents the presence of lactate produced due to anaerobic metabolism from poor tissue perfusion.

Recently, studies have found that base deficit correlates well with mortality in certain populations vulnerable to traumatic injury, particularly the elderly. However, these studies also indicate that base deficit data require careful interpretation. In the elderly, it may be that smaller measured based deficits can still indicate life-threatening injury, when compared to what is seen in younger seriously injured patients.[4]

Base deficit also appears to be an approximate marker of the adequacy of resuscitation, though it has its limitations. Some studies have suggested that base deficit can be falsely reduced in the setting of saline resuscitation due to a dilutional effect, limiting its correlation with serum lactate.[5,6] However, in the acute setting, it appears that base deficit may help stratify the severity of the injured patient at the volumes typically given in the initial ED or pre-hospital setting (2 liters of normal saline).[7]

Given that base deficit has value in the initial assessment and resuscitation of traumatically injured patients, it should be considered a standard order in trauma patients at risk for serious injury or requiring hospitalization.

Arterial and Venous Blood Gas. The question then arises about how best to obtain an accurate base deficit measurement. The most common means of acquiring blood to measure base deficit is by blood gas, either from an arterial or venous site. Although an arterial blood gas has the advantage of providing accurate information on oxygenation in the traumatically injured patient with such poor perfusion that pulse oximetry is unobtainable, it requires an additional site of cannulation during resuscitation, and it is more painful for the patient. Venous blood gas can be obtained easily during standard intravenous catheter placement but provides little information about arterial oxygen saturation. A venous blood gas is useful in assessing oxygen consumption and venous oxygen saturation if obtained from a central site. Additionally, there is evidence in the literature that blood gases can reveal the presence of metabolic acidosis that would otherwise be unsuspected in trauma patients during their initial presentation.[8]

Various studies have assessed the correlation between central venous and arterial blood gases in the trauma patient. Malinoski et al found that in general, central venous blood gases provided accurate and correlating values for pH, pCO_2, and base deficit, although knowledge of the exact range of correlation was necessary for use in trauma resuscitation.[9] Schmelzer et al found in one small study of 100 trauma patients that venous base deficit may be a more accurate predictor of mortality, perhaps due to its superiority as a marker of tissue perfusion.[10] Finally, serum bicarbonate measurement itself may correlate well with arterial base deficit, suggesting that venous samples can be used in the initial evaluation of the need for trauma resuscitation.[11]

Overall, there is evidence to support routine blood gas analysis for base deficit and metabolic acidosis evaluation in trauma patients suspected on initial history and physical examination as being at risk of serious injury. However, the decision as to whether to obtain a venous or arterial blood gas

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is best determined by the needs of the individual patient with consideration of arterial oxygen saturation and tissue perfusion status.

Lactate. Lactate production is a by-product of anaerobic metabolism. Its measurement serves as an adjunct for assessing the presence of tissue hypoperfusion and hypoxemia, a marker that may be a valuable tool to determine which traumatically injured patient is at risk for morbidity and mortality as well as the adequacy of resuscitation. The measurement of lactate in the evaluation of trauma patients often goes together with the obtaining of arterial or venous blood gas to determine the presence of a base deficit.

The evidence in the most recent literature suggests that lactate, as a more specific measurement of anaerobic metabolism, may be a better predictor than base deficit for mortality and perhaps even morbidity in the trauma patient. In a mixed population of trauma and non-trauma patients admitted to a surgical intensive care unit, Husain et al found that initial lactate level correlated well with patient mortality in contrast to initial base deficit, which did not. In addition, clearance of lactate within 24 hours was associated with a 10% incidence of mortality. The mortality rate jumps to 24% if the lactate is not cleared by 48 hours and 67% if the lactate is not cleared at all. The patient's level of function at discharge also correlated with initial lactate level and lactate clearance during resuscitation.[12] Lactate also appears to correlate well with standard assessment scores of injury severity, indicating its value as a biochemical measurement of trauma morbidity and risk of mortality.[13] Finally, for patients in the intensive care unit for prolonged periods of time, lactate appears more predictive than base deficit for mortality.[14]

Alcohol and illicit drug use are recognized risk factors for traumatic injury.[15,16] Given that both of these can cause a metabolic acidosis when ingested, the question arises as to whether the presence of alcohol or illicit drugs on standard screening in trauma patients confounds the utility of base deficit and lactate as a potential assessment tool. Dunne et al studied more than 15,000 traumatically injured adults from 1998 to 2000, and found that lactate and base deficit independently were predictive of mortality and intensive care unit/hospital length of stay, regardless of the presence of alcohol or illicit drug use at the time of injury.[17]

Overall, lactate appears to correlate more accurately with traumatic mortality than base deficit alone. For acute care providers of trauma patients, lactate should also be part of the standard laboratory evaluation of individuals deemed to be at risk for serious injury requiring hospitalization. Lactate clearance should be assessed over a 48-hour period to determine the adequacy of resuscitation in the face of ongoing tissue hypoperfusion and hypoxemia.

Strong Anion Gap. While base deficit and lactate are useful measurements in the laboratory evaluation of trauma patients, they may also be integrated into one measurement by calculating the strong anion gap. Unlike a standard anion gap calculation ($[Na^+ + K^+] - [Cl^- + HCO_3^-]$), the strong anion gap is calculated using additional cations and anions ($[Na^+ + K^+ + Mg^{2+} + Ca^{2+}] - [Cl^- +$ lactate (mEq/L)$]$). The advantage of this calculation in comparison to the standard anion gap calculation is that it can differentiate the etiology of acute metabolic acidosis more accurately in the critically ill patient, as shown in studies in a variety of critical care settings.[18,19]

For patients presenting initially to the emergency department with potentially serious traumatic injury, Zehtabchi and colleagues found that strong anion gap could differentiate severely ill versus not-severely ill trauma patients, though not as well as base deficit.[20] In contrast, Kaplan et al found that in patients with major vascular injury from trauma to the torso or extremity, strong anion gap was most predictive of mortality in comparison to initial pH, standard anion gap, base deficit, and lactate.[21]

Strong anion gap can be easily calculated from the initial laboratory evaluation of trauma patients, but further study is required to identify the timing and value in trauma resuscitation that will provide the most useful information. It may be most useful as a predictor for mortality in combination with other markers of resuscitation such as base deficit and lactate. **Table 1** lists those tests that are readily obtainable during the initial trauma resuscitation that can be followed to determine adequacy of resuscitation.

Table 1. Trauma Laboratory Evaluation to Assess Adequacy of Resuscitation

BLOOD GAS	
Arterial and Venous	Assessment of pH and oxygenation (arterial blood gas)
Base Deficit	Assessment of state of tissue perfusion or presence of anaerobic metabolism
LACTATE	Assessment of presence of anaerobic metabolism and poor tissue perfusion
STRONG ANION GAP	Assessment of cause of metabolic anion gap acidosis — useful in differentiating whether due to traumatic injury versus other underlying medical conditions
STANDARD ANION GAP	Assessment of tissue perfusion and anaerobic metabolism
BICARBONATE LEVEL	Assessment of tissue perfusion — indicates presence of anaerobic metabolism

Coagulopathy

The deadly triad of hypothermia, acidosis and coagulopathy has been linked to a poor prognosis in trauma patients. Clinically, this condition is recognized by continued bleeding from wounds, access sites, mucosal/serosal surfaces, and formation of hematomas at non-injury sites despite interventions.[22] Hypothermia, acidosis and hemodilution, in the past were thought to contribute to coagulopathy. Disseminated intravascular coagulopathy (DIC) can also be associated with the coagulopathy of trauma. Fat, amniotic, or cerebral emboli can result in DIC through consumption of clotting factors. Pregnant patients should be worked up for coagulopathy. A high suspicion should also be maintained with geriatric patients for increased risk of bleeding secondary to anticoagulation medications. Laboratory studies that help determine the presence of coagulopathy and DIC in particular include platelet count, prothrombin time, activated partial thromboplastin time, fibrin split products and fibrinogen.[23] **Table 2** shows the tests that can be used to assess for the presence of trauma-related coagulopathy and DIC.

Table 2. Laboratory Evaluation for Trauma-related Coagulopathy and Expected Findings during Disseminated Intravascular Coagulation (DIC)

PLATELET COUNT	Expected to be decreased during DIC from consumption
PROTHROMBIN TIME (PT)	Expected to be increased during DIC from consumption of clotting factors and poor clotting factor function
INTERNATIONAL NORMALIZED RATIO (INR)	Expected to be increased during DIC from consumption of clotting factors and poor clotting factor function
PROTHROMBOPLASTIN TIME (PTT)	Expected to be increased during DIC from consumption of clotting factors and poor clotting factor function
FIBRINOGEN LEVEL	Expected to be decreased during DIC from consumption due to rapid conversion to fibrin and other degradation products
FIBRIN SPLIT PRODUCT LEVEL	Expected to be increased during DIC from consumption of fibrinogen
D-DIMER	Expected to be elevated during DIC from increased intravascular clot formation and degradation

Resuscitation has traditionally focused on correcting hypothermia and acidosis to prevent the development of coagulopathy. Recently studies focusing on damage control resuscitation and massive transfusion protocols have shown coagulopathy to be present from the onset of injury, not just secondary to fluid resuscitation and hypothermia.[24-26] Acidosis leads to consumption, dysfunction, and decreased production of coagulation factors; while hypothermia inhibits platelet adhesion and activation. Specifically, a pH ≤ 7.15 results in decreased activity of factor VIIa and factor Xa complexes, as well as a reduction in coagulation factors overall.[22] While hypothermia and acidosis have been major targets of resuscitation, recent studies have indicated that intervention for coagulopathy should be initiated early in resuscitation. For patients requiring massive transfusion, systolic blood pressure should be maintained at least at 90mmHg with the use of plasma, packed red blood cells, and possibly recombinant factor VIIa. Early intervention with replacement of coagulation factors and platelets results in decreased transfusion requirements. Recommendations for replacement varies from one to three units of fresh frozen plasma for each transfused unit of packed red blood cells.[26]

Hemoglobin vs Hematocrit

Hemorrhage is the second-leading cause of death related to injury. Identifying hemorrhage early in resuscitation remains a challenge. It has been suggested that initial hematocrit may not accurately reflect blood loss because both plasma and red cells are lost equally. As such, the utility of standard hematocrit versus hemoglobin testing as a determinant of ongoing blood loss during trauma resuscitation has been questioned. Nijboer et al compared hemoglobin and hematocrit levels in trauma patients; they found both values to be equivalent in their ability to indicate ongoing blood loss, with either being useful in evaluation of trauma patients.[27] Hematocrit may therefore be as useful as hemoglobin in assessing ongoing blood loss in the trauma patient.

Bruns and colleagues performed a retrospective study investigating the utility of early hemoglobin measurement for identifying bleeding. Hemoglobin was measured at the bedside within 30 minutes of arrival. Lower values correlated with hemorrhage, as well as, increased heart rate, lower systolic blood pressure, lower pH and base deficit, increased need for blood transfusion and volume resuscitation. They found a hemoglobin < 10g/dL was associated with a greater than three-fold increase in the need for intervention to control the hemorrhage, and suggest that hemoglobin < 10g/dL be used as an indication for an evaluation to identify an occult site of hemmorhage.[28] Zehtabchi et al studied serial hematocrit measurements for identifying occult hemorrhage. They found no relation between change in hematocrit and volume of intravenous fluids administered. A change in hematocrit > 5g/dL in 4 hours was found to be specific for major injury, though a lack of decrease in hematocrit could not be used to exclude major injury.[29] In patients younger than age 55 with no heart disease, a hemoglobin > 7g/dL should be maintained.[23]

Given that hemoglobin and hematocrit levels routinely are acquired with complete blood counts, they may be used in concert and in a serial manner to assess for the presence of ongoing hemorrhage in trauma patients.

Leukocytosis

It is common for acute trauma patients to have a marked leukocytosis on arrival to the hospital. This is felt to be due to the cathecholamine and adrenergic response that accompanies the physiological stress of trauma and the resultant demargination of white blood cells in a classic acute phase reaction. However, it does not appear that leukocytosis by itself can be used as a marker for injury type or need for intervention. Chang et al evaluated whether degree of leukocytosis on arrival to the hospital correlated with severity of injury and need for therapeutic intervention. They found that leukocytosis was not associated with injury location or need for intervention, but was correlated with injury severity.[30]

Morell and colleagues also found that leukocytosis correlates well with injury severity and length of intensive care stay after trauma, but did not study how it correlated with specific injury or need for intervention.[31] Overall, the presence of leukocytosis suggests a more severe injury in the trauma patient, but is very non-specific and should not be used by itself as determination of the need for further evaluation and therapeutic intervention.

Chemistry Profile

It is common when traumatically injured patients present in the acute care setting to obtain routine chemistry profiles, consisting of serum electrolytes, bicarbonate, glucose, BUN, and creatinine. However, studies to date have found little evidence that this evaluation changes the management of non-critically ill trauma patients. Tortella et al found that only 6 of 913 assessed patients presenting to the ED with traumatic injuries required change in resuscitation plans due to the findings on routine serum chemistry profiles despite 89% of assessed patients having some abnormality on this lab test. Those most likely to require change in treatment plan were patients over age 50, patients on anti-hypertensive medications, and patients with a Glasgow Coma Scale (GSC) < 10.[32] In a series of 500 trauma patients, Namias and colleagues found that including amylase and coagulation profiles in addition to a routine serum chemistry profile added little information that would change resuscitative measures. Patients required intervention in < 1% of abnormalities in serum chemistry profiles or amylase, and < 5% of coagulation profiles.[33] The evidence indicates that routine chemistry profiles provide little information that changes the initial resuscitation of trauma patients and should not be ordered as a matter of protocol.

Ionized Calcium

In contrast to routine chemistry profiles, there is evidence to suggest initial ionized calcium level may be useful in assessing the risk of mortality in trauma patients. Cherry et al found that decreased ionized calcium was associated with prehospital hypotension and increased mortality, regardless of injury severity, age, or base deficit. This finding was not expected given that acidosis results in decreased calcium binding and increased levels of ionized calcium.[34] Vivien et al found that low ionized calcium levels may be due to the infusion of colloid during resuscitation and severe tissue ischemia/reperfusion injury.[35] The evidence suggests that ionized calcium should be measured in patients who are found to be severely injured and potentially will require blood transfusions as part of their resuscitation.

Glucose

While routine glucose measurement at initial presentation does not often change initial treatment of trauma patients, poor glycemic control in critically ill patients is associated with increase mortality. Gale and colleagues found that in their cohort of critically ill trauma patients requiring treatment in an intensive care unit, maintenance of serum glucose below 140 mg/dL was associated with a decreased mortality rate of 22% versus 9% in the controlled population. This effect was more pronounced in non-diabetic patients (9% mortality vs 32% mortality).[36] For patients who are critically injured, it is necessary to aggressively control serum glucose, often using intravenous insulin drips with frequent blood glucose evaluation.

Cardiac Markers

The diagnosis of myocardial contusion following blunt chest trauma remains a challenge. Patients can present with a wide range of signs and symptoms including dysrhythmia, myocardial infarction and cardiac tamponade. Plautz et al presented two cases of post-traumatic myocardial infarction with evaluation by ECG, serum cardiac markers, and echocardiogram. Both cases exhibited ST-elevation on ECG. Sinus tachycardia is the most common finding on ECG evaluation for cardiac injury; nonspecific ST-T wave changes, conduction abnormalities, right bundle branch block, interventricular delay, and ST elevation/depression also may be associated with myocardial contusion. Cardiac markers also have potential for use in conjunction with an ECG. Normal troponin levels six hours after injury combined with a normal admission ECG in a stable patient can exclude significant blunt cardiac injury.[37] In patients with suspected cardiac injury, ECG and cardiac markers should be obtained as part of the ongoing laboratory evaluation of the patient.

Recent studies focusing on the utility of B-type natriuretic peptide (BNP) as a marker for early blood loss in trauma patients have not been definitive. Kia et al found correlation between BNP levels, intravascular volume loss, and drop in hemoglobin levels. BNP levels below-normal (≤ 5) on admission were associated with need for intravascular volume repletion, transfusion, or decrease in hemoglobin of 3 g/dL.[38] Further studies are needed before routine BNP levels are obtained during trauma resuscitations. Given that many patients with underlying congestive heart failure can have elevated BNP levels but remain asymptomatic, the utility of BNP in routine laboratory testing of the trauma patient is questionable until a targeted patient population can be identified.

Drug / Alcohol Screening

The incidence of alcohol and drug intoxication amongst trauma patients is high. Some studies cite up to a 50% prevalence of alcohol intoxication at the time of trauma.[39] Demetriades et al studied the relationship between alcohol and illicit drug use and injury severity and traumatic fatalities. A high percentage (42.7%) of fatalities tested positive for alcohol or illicit drugs. The prevalence of a positive screen was greater in patients of male sex, age 15–50, Hispanic or African American race, and in those with penetrating traumatic injury.[40] Additionally, drug and alcohol use in pregnant patients is prevalent, and routine testing of this patient population is advocated.[41]

Tien and colleagues studied the relationship between alcohol and severe traumatic head injury. Their results support findings of potential neuroprotective effects of low doses of alcohol in brain injury. Patients with levels < 240mg/dL demonstrated improved mortality versus patients with no alcohol detected. The protective effects of alcohol may be attributed to inhibition of excitotoxicity at the NMDA-receptors. High alcohol levels (> 240 mg/dL) correlated with increased mortality in patients with severe brain injury.[39] While this one study's result raises the intriguing possibility of alcohol having neuroprotective properties in brain injured patients, further investigations are required prior to consideration in clinical practice. What is clear is that the high prevalence of illicit drug and alcohol use among trauma patients requires that their presence be screened for as part of the initial assessment. This information can aid in discovering the etiology of injury and provide prognostic information.

Urinalysis / Urine Pregnancy Testing

Bladder injury can be an occult, but devastating, traumatic injury. Assessing for this injury often requires cystography to determine if the bladder is intact and if a bladder rupture is intra- versus extra-peritoneal. Previously, acute care providers used the urinalysis, specifically the presence of greater than 50 red blood cells/high powered field to determine the need for invasive testing for bladder injury. However, this approach would result in numerous patients with microscopic hematuria undergoing cystography despite their hematuria being due to non-traumatic causes. Recent studies have found that gross hematuria is both sensitive and specific for bladder injury and that urinalysis with microscopic hematuria adds little to this evaluation.[42] As such, routine urinalysis is not necessary in the laboratory evaluation of trauma patients. However, urine pregnancy testing is vital in reproductive-age females who have suffered trauma, as the presence of pregnancy can affect medication choices, diagnostic evaluation, and treatment options.

Special Populations

Pregnancy. Trauma in pregnancy focuses on evaluation of the mother and fetus, and ß-HCG testing should be performed on all female patients of childbearing age. Additional initial laboratory studies include hemoglobin, hematocrit, coagulation studies, type and cross match, fibrinogen, urinalysis, urine drug screen, alcohol level, serum bicarbonate, blood gas, lactate, and Kleihauer-Betke (KB) test. Liver function tests may also be useful to evaluate for abdominal injury. Blood gas, lactate, and serum bicarbonate may be used to evaluate for maternal acidosis, which studies have correlated with fetal outcome.[43] Patteson et al found abnormal coagulation studies, serum bicarbonate, low diastolic blood pressure, and respiratory rate to be most predictive of maternal–fetal outcomes in traumatically injured pregnant women. In addition, they found that gestational age also correlated with fetal outcome.[41] Fibrinogen may be useful to evaluate for placental abruption and disseminated intravascular coagulopathy. Normal fibrinogen levels should be concerning for DIC, as levels are elevated in pregnancy.[44] Patteson and colleagues also found that D-dimer testing is useful to evaluate for thrombosis or fibrinolysis abnormalities.[41]

The KB test is a marker of fetomaternal hemorrhage and uterine-placenta trauma, which is associated with increased risk of preterm labor. Meroz et al suggest performing a KB test on all patients with a pregnancy > 12 weeks.[44] An Rh-negative patient with a positive KB test should receive Rh-immune globulin. There is debate over whether the KB test correlates with placental abruption, and studies have shown conflicting results. Cahill and colleagues did a prospective study investigating the risk of placental abruption or adverse outcomes in patients > 24 weeks gestation with minor trauma. Of nine patients with a positive KB test, only one patient had a placental abruption. They suggest physical exam, fetal assessment, monitoring, and patient counseling for warning signs/symptoms of abruption in patients > 24 weeks with mild trauma.[45]

In the lab evaluation of the traumatically injured pregnant female, therapy focused on the mother's well being will also be beneficial to the fetus and lab evaluation in this patient population requires some additions, such as the KB test to aid in the treatment of the mother and prevention of harm to the fetus.

Pediatric. The pediatric trauma patient population raises specific challenges in laboratory evaluation. Routine testing can easily agitate and traumatize already vulnerable younger patients. Careful consideration in the ordering of laboratory testing is warranted. Keller et al questioned the utility of routine laboratory studies in pediatric trauma patients, where diagnostic imaging plays a key role in management. In their review, hypokalemia, hyperglycemia, and coagulopathy were associated with intracranial injuries, a low CO_2 correlated with a worse outcome, elevated transaminases suggested liver injury, and hematuria predicted intra-abdominal injury. While the presence of laboratory abnormalities correlated with injury severity scoring, they often did not result in interventions or changes in management. The authors suggest performing a screening hematocrit and urinalysis on all patients, coagulation studies if GCS < 15, and additional laboratory testing based on the physical exam.[46]

Blunt trauma is common in children, especially blunt abdominal trauma. Some advocate that patients with low suspicion for intra-abdominal injury may be managed with laboratory studies (hemoglobin/hematocrit, transaminases, urinalysis), +/- ultrasound, and observation in place of CT scans. Amylase and lipase may also be useful aids for the diagnosis of pancreatic injuries. Controversial is the existence of a specific value of a transaminase that excludes a liver injury. Some studies have suggested aspartate aminotransferase (AST) > 400 and alanine aminotransferase (ALT) > 250 correlate with hepatic injury. However, a review by Karam et al found that low transaminases could not be used to exclude hepatic injury. Of the 16 patients with liver injury, 10 had AST < 450 and 7 had ALT < 250.[47] For pediatric patients with intra-abdominal injury who are hemodynamically stable, management has shifted to a non-operative approach. In addition to radiologic imaging, patients are monitored with serial laboratory studies, including hemoglobin/hematocrit, electrolytes, liver function tests (LFTs), and lactate levels.

Cardiac injury in pediatric patients is uncommon. As with adult patients, no gold standard exists for the diagnosis: similar to adult patients, cardiac markers may also have some utility. While studies have shown CK-MB to have a low sensitivity and specificity, elevated troponin I has been associated with injury. Normal troponin levels should be repeated 4 to 6 hours after the initial screening test to exclude cardiac injury if initially suspected. ECGs may be normal or show non-specific changes and a normal ECG does not exclude injury. Left ventricular injury may show new Q waves or ST abnormalities, while right ventricular injury may produce a right bundle branch block, AV block, or ventricular arrhythmias. ECGs should be repeated when there is major blunt chest trauma.[48] Overall, judicious selection of what laboratory testing pediatric trauma patients should receive is advised based on the initial clinical history and physical examination.

Geriatric. Trauma is the fifth leading cause of death in patients older than 65 years of age. Despite comprising only 12% of trauma patients, the elderly represent 28% of deaths related to trauma. Confounding the management of geriatric trauma patients are their co-morbidities and multiple medication regimens. Electrolytes, LFTs, and blood glucose should be part of the initial laboratory studies because of the prevalence of diabetes, liver disease, and renal disease in the geriatric population. A screening blood gas and lactate should be drawn to look for hypoperfusion and guide resuscitation. An ECG should be performed to look for arrhythmias or acute ischemic events.[49]

Coagulation studies should also be part of the initial evaluation of a geriatric trauma patient. The high-incidence of falls and motor vehicle accidents, combined with the use of warfarin, clopidogrel, and aspirin leads to increased risk of bleeding. Pieracci et al studied the relationship between anticoagulation and traumatic brain injury in elderly patients. There was no statistical significance between use of clopidogrel and intracranial hemorrhage or aspirin use and intracranial hemorrhage. Patients with INR ≥ 2 had an increased likelihood of intracranial hemorrhage and mortality, lower GCS, and more severe brain injuries.[50] Aschkenasy and Rothenhaus cite an increased risk of death in aspirin and clopidogrel patients with intracranial injury.[49] Geriatric trauma patients present the compounded issue of disease due to injury as well as underlying medical conditions that lead to a reduced ability to recover compared to non-elderly patients without chronic medical illnesses. Therefore, liberal laboratory evaluation from the onset of resuscitation can help with what is often a multi-pronged management of both trauma- and non-trauma-related factors for recovery.

Routine Laboratory Testing

Based on the above discussion of currently available evidence, the question arises as to what should constitute routine laboratory testing in the trauma patient. This question is challenging, as there is minimal evidence to suggest that routine comprehensive laboratory testing is useful in trauma patients as a whole. However, specific situations should guide the need for specific laboratory testing.

A thorough history and physical examination of the trauma patient should be the first step in determining the need for laboratory testing. In the injured patient, this should include both an understanding of the mechanism of trauma as well as the underlying medical and medication history that preceded the injury. Only with such a history can treatment providers determine how best to assess the patient. For example, a patient who presents with back pain after a fall who is otherwise healthy may require little beyond analgesia, while a patient on coumadin due to a previous heart condition may require extensive observation and serial hemoglobin measurements along with blood gas, coagulation studies, and lactate measurements to evaluate for the presence of internal hemorrhage.

Physical examination also plays a crucial role in the determination of how best to order a targeted laboratory evaluation in the trauma patient. Rather than ordering on every patient every conceivable laboratory test, physical examination can narrow what tests should be assessed. For example, a high-energy motor vehicle accident in which the patient only had a shoulder belt on with steering wheel impact and deformity and resultant chest injury may require serial cardiac markers and ECG assessment. The presence of gross blood on urination mandates the evaluation for bladder injury, usually by cystography. A clearly gravid female trauma patient would raise the issue of fetal compromise and maternal–fetal hemorrhage that would result in the ordering of a KB test. Overall, the combination of history and physical examination can aid in decisions of how best to assess the trauma patient from the laboratory perspective.

Laboratory Testing Based on Degree of Trauma

Once the initial history and physical examination is performed on a trauma patient, the severity and potential for injury should be more readily apparent. This will guide acute care providers as how to best evaluate these individuals using laboratory testing. Low-mechanism injury patterns in healthy individuals generally do not require laboratory testing. This may range from patients with injuries as simple as an ankle sprain to those in low-energy motor vehicle accidents (e.g., <25 mph, ambulatory at scene, full restraints with no airbag deployment). In such patients, laboratory testing is superfluous. As discussed above, most large-scale studies on the utility of lab testing in trauma have only found support for utility of testing in more seriously injured patients or patients requiring serial evaluations.

In contrast, low-energy mechanisms affecting medically fragile patients require a more extensive laboratory evaluation. The classic example would be an elderly patient who falls and has a brief loss of consciousness. Should the history reveal that the patient takes anti-coagulation medication, the ordering of hemoglobin/hematocrit and coagulation profiles would be warranted. A physical examination finding of a pacemaker/defibrillator in a patient amnestic to the event should prompt consideration of cardiac etiologies, such as arrhythmias and myocardial ischemia/infarction; diagnostic testing would include ECG and cardiac markers. Overall, knowledge of the underlying medical and surgical history of the patient will aid in determining whether more extensive testing is required.

In young, healthy patients with high-energy/risk-traumatic injuries, the laboratory testing algorithm should be focused on obtaining information that can be assessed in a serial manner. For example, a young, healthy female involved in a high-speed motorcycle collision who presents with hypotension will require assessment of the adequacy of resuscitation from initial injury to discharge from the hospital. In this case,

Table 3. Optimal Laboratory Evaluation of Trauma Patient Based on Energy of Mechanism and Underlying Health Status

LOW-ENERGY AND HEALTHY PATIENT
History and physical examination alone typically suffices
Imaging of affected area(s) as needed
HIGH-ENERGY AND HEALTHY PATIENT
History and physical examination
Complete blood count, blood gas, serum lactate, drug/alcohol testing, and urine pregnancy test in reproductive-age females
If hospitalized, metabolic profile, glucose, ionized calcium; coagulation profile if transfusion is anticipated
LOW-ENERGY AND MEDICALLY FRAGILE PATIENT
History and physical examination to determine cause of trauma
Low threshold for ECG and cardiac markers in patients with history of syncope or unexplained falls
Complete blood count and coagulation profiles in patients on blood-thinning medications
Medication levels where appropriate (seizure and cardiovascular agents)
HIGH-ENERGY AND MEDICALLY FRAGILE PATIENT
History and physical examination to determine cause of trauma, underlying health status and nature of injuries
Complete blood count, coagulation profile, blood gas, serum lactate, metabolic profile, glucose, ionized calcium, medication levels, ECG, and cardiac markers
PREGNANT WOMEN
Kleihauer-Betke testing in addition to above assessment based on energy of mechanism and health status
PEDIATRIC PATIENTS
Greater emphasis on history, physical examination and extended period of observation as opposed to extensive laboratory evaluation
Complete blood count serially if concern for ongoing hemorrhage

it is recommended at a minimum to order a complete blood count, arterial or venous blood gas (depending on ability to assess oxygenation), serum lactate, drug/alcohol screening (given the high incidence of use in traumatically injured individuals and their contribution to particular injury patterns and outcomes), and urine pregnancy testing. Should the patient require admission to the hospital, other measurements will be required to modify the patient's treatment plan, including glucose, metabolic profiles, and potentially ionized calcium levels and coagulation profiles, if blood product transfusion is expected or coagulopathy is a concern. In essence, the higher-energy mechanism of trauma will add to the scope of laboratory testing regardless of initial health status of the patient.

For the medically fragile or geriatric trauma patient with a high-energy injury mechanism, liberal laboratory testing is recommended. Acute care providers, in this case, are dealing with two patients — a trauma patient and an acutely ill medical patient. Nearly all the tests described in this article will be useful and should be ordered.

Hemoglobin and hematocrit are necessary, as many of these patients start with a baseline anemia and may require blood product transfusion at an earlier stage, especially if they have an underlying cardiac condition. Coagulation profiles aid in the assessment of the many patients on anticoagulants requiring emergent reversal of their blood-thinning status. Blood gas and lactate levels help to determine adequacy of resuscitation and can be supplemented with the strong anion gap calculation. Similarly, chemistry profiles can provide invaluable information regarding underlying renal status, need for aggressive blood sugar management, and future prognosis based on ionized calcium levels. Drug levels can also aid in the assessment of the underlying cause of injury, as in the case of supratherapeutic dilantin or digoxin levels leading to metabolic derangements that cause elderly patients to fall and injure themselves.

Finally, cardiac evaluation can aid in the understanding of the underlying etiology of the trauma, as in the case of myocardial ischemia/infarction, as well as monitoring for ongoing cardiac injury from trauma. Overall, elderly patients involved in high-energy trauma are at much higher risk of morbidity and mortality than the young, requiring extensive laboratory testing to allow for improved treatment measures and outcomes. **Table 3** provides an overview of optimal laboratory testing of the trauma patient based on the energy of the traumatic mechanism and the underlying medical status of the patient.

Pediatric patients represent a special population in trauma. Their laboratory assessment should be focused based on initial history and physical examination, as in the adult population. Multisystem trauma may require extensive testing as previously described in adults, but often, history and physical examination with the potential addition of hemoglobin to assess for ongoing hemorrhage along with careful observation over time is more useful than extensive serum laboratory tests.

Conclusion

The laboratory evaluation of the trauma patient should be focused and based on the underlying health issues, mechanism of injury, and the patient's history and physical condition. Treatment providers should use their initial clinical history and physical examination to guide the selection of testing and understand the limitation of the findings in these tests. Future studies will likely refine and add to the repertoire of available laboratory testing in the trauma patient to aid in their management.

CME Questions

1. The base deficit is:
   A. a measurement of the deficit of bicarbonate given the measured pH and pCO_2 on blood gas.
   B. a measurement of ionized calcium in a trauma patient.
   C. often due to the presence of ketones in the severely injured trauma patient.
   D. definitive in ruling out severe traumatic injury.

2. Elevated lactate level in a trauma patient:
   A. indicates adequate tissue perfusion and resuscitation.
   B. proves the presence of anaerobic metabolism.
   C. correlates poorly with trauma-related morbidity and mortality.
   D. causes a metabolic alkalosis.

3. The strong anion gap calculation is:
   A. $[Na^+ + K^+]-[Cl^- + HCO_3^-]$.
   B. $2Na^+$ + BUN/2.8 + Glucose/18 + Ethanol/4.2.
   C. 0.8 (normal albumin–patient's albumin) + serum calcium.
   D. $[Na^+ + K^+ + Mg^{2+} + Ca^{2+}] - [Cl^- +$ lactate (mEq/L)].

4. Lab studies that can help specifically diagnose coagulopathy include:
   A. metabolic profile, glucose, and KB test.
   B. base deficit, strong anion gap.
   C. platelet count, PT, PTT, fibrinogen, fibrin split products.
   D. amylase, lipase, liver function tests.

5. The time after injury required to rule out suspected cardiac trauma using troponin is (in hours):
   A. 4
   B. 6
   C. 12
   D. 24

6. It is a general recommendation that patients younger than age 55 with no history of cardiac disease be maintained with a hemoglobin *greater* than:
   A. 5 g/dL
   B. 7 g/dL
   C. 10 g/dL
   D. 12 g/dL

7. What urinary finding is associated with traumatic bladder injury?
   A. Gross hematuria
   B. Microscopic hematuria
   C. Microscopic pyuria
   D. Microscopic epithelial cells

8. The Kleihauer-Betke test is an indication of:
   A. trauma to the liver.
   B. trauma to the kidney.
   C. mixing of maternal and fetal blood.
   D. trauma to the lungs.

9. The prevalence of alcohol use in trauma patients may be as high as:
   A. 20%.
   B. 30%.
   C. 40%.
   D. 50%.

10. What lab finding in the elderly trauma patient has a direct correlation with increase mortality/morbidity from brain injury?
   A. Hyponatremia
   B. INR
   C. Hypercalcemia
   D. Hypoglycemia

Answers: 1. A; 2. B; 3. D; 4. C; 5. B; 6. B; 7. A; 8. C; 9. D; 10. B.

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CNE/CME Objectives

Upon completing this program, the participants will be able to:

a.) discuss conditions that should increase suspicion for traumatic injuries;

b.) describe the various modalities used to identify different traumatic conditions;

c.) cite methods of quickly stabilizing and managing patients;
and

d.) identify possible complications that may occur with traumatic injuries.

CNE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge.

To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you must complete the evaluation form provided and return it in the reply envelope provided in order to receive a letter of credit.** When your evaluation is received, a letter of credit will be mailed to you.

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